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JET PROPULSION

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Journal of the
AMERICAN ROCKET SOCIETY
Rocketry . . . . . Jet Propulsion Sciences . . . . . Astronautics

VOLUME 27 MARCH 1957 NUMBER 3

High Altitude Sounding Rockets Issue

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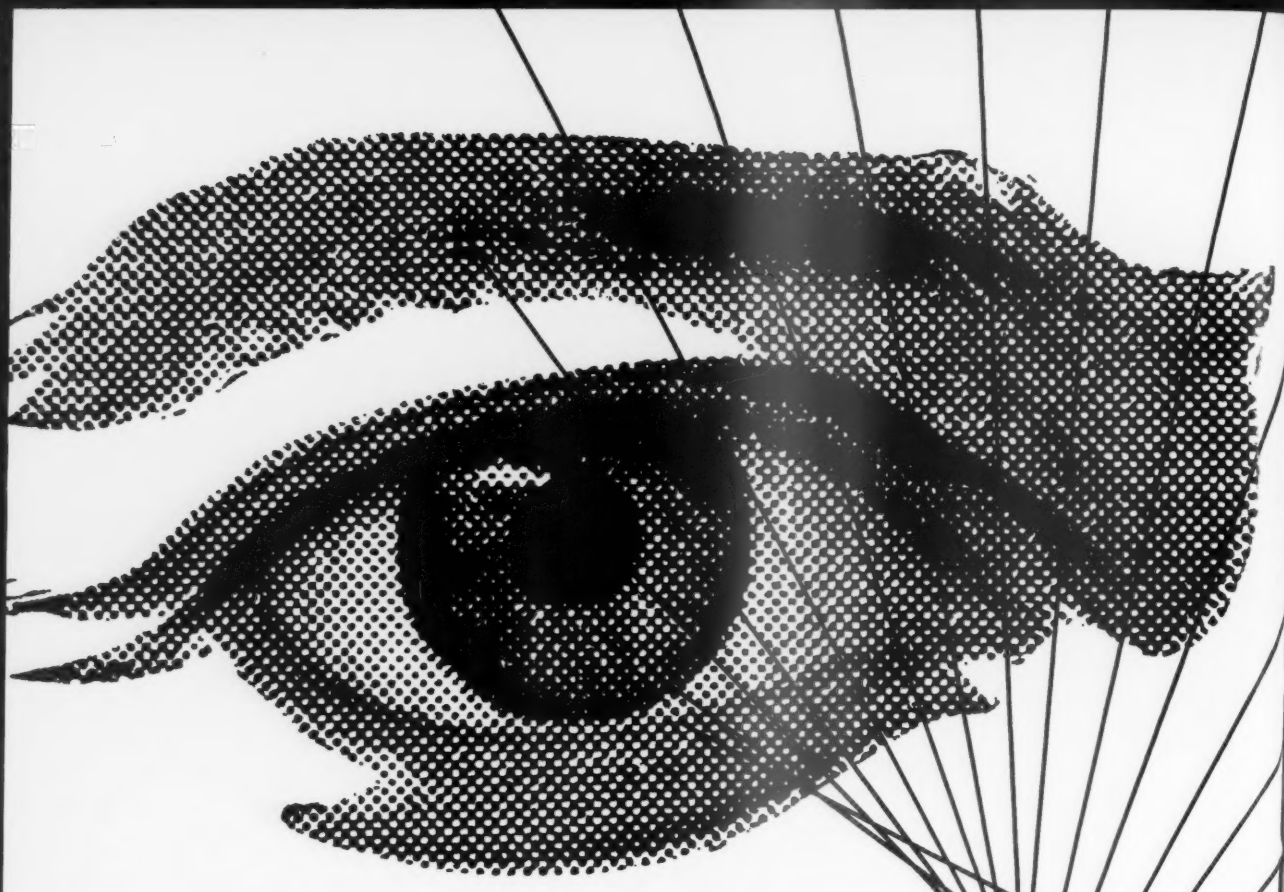

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JET PROPULSION, the Journal of the American Rocket Society, is devoted to the advancement of the field of jet propulsion through the publication of original papers disclosing new knowledge and new developments. The term "jet propulsion" as used herein is understood to embrace all engines that develop thrust by rearward discharge of a jet through a nozzle or duct; and thus it includes systems utilizing atmospheric air and underwater systems, as well as rocket engines. JET PROPULSION is open to contributions, either fundamental or applied, dealing with specialized aspects of jet and rocket propulsion, such as fuels and propellants, combustion, heat transfer, high temperature materials, mechanical design analyses, flight mechanics of jet-propelled vehicles, astronautics, and so forth. JET PROPULSION endeavors, also, to keep its subscribers informed of the affairs of the Society and of outstanding events in the rocket and jet propulsion field.

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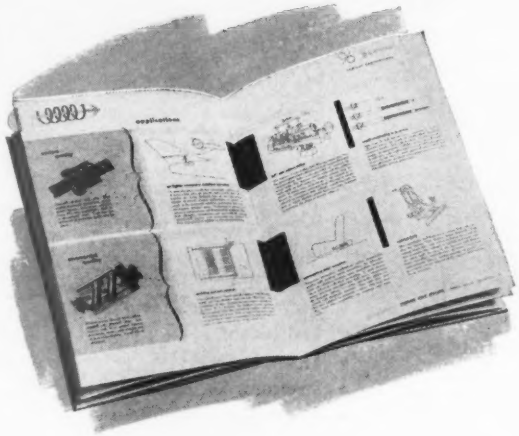

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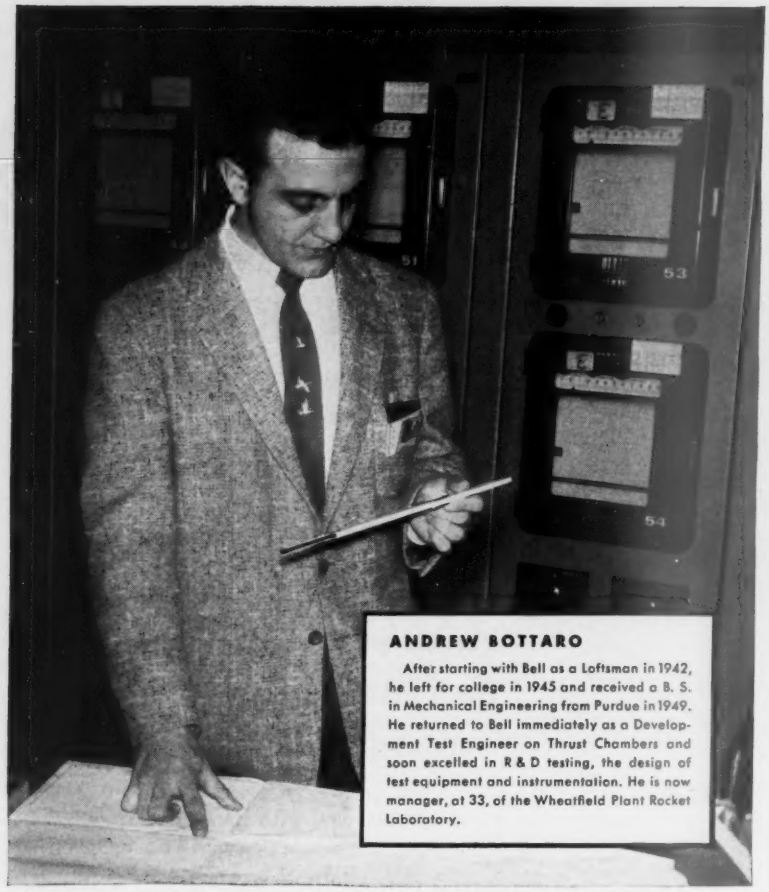

ANDREW BOTTARO

After starting with Bell as a Loftsman in 1942, he left for college in 1945 and received a B. S. in Mechanical Engineering from Purdue in 1949. He returned to Bell immediately as a Development Test Engineer on Thrust Chambers and soon excelled in R & D testing, the design of test equipment and instrumentation. He is now manager, at 33, of the Wheatfield Plant Rocket Laboratory.

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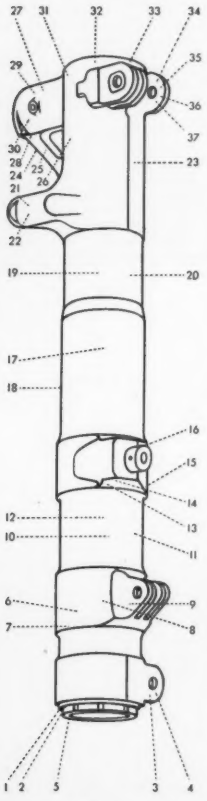

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5	75	80.8	65	72.3	7	8
6	70	76.4	60	68.8	3	4
7	65	72.4	55	63.6	2	4
8	75	83.7	65	73.9	7	7
9	70	75.2	60	64.3	3	8
10	70	71.3	60	60.0	3	6
11	65	71.0	55	67.0	2	4
12	75	82.2	65	72.0	7	13
13	70	74.2	60	65.8	3	3
14	70	75.2	60	70.2	3	3
15	70	73.4	60	68.2	3	3
16	70	75.3	60	66.0	3	6
17	75	82.2	65	72.1	7	10
18	65	71.6	55	64.2	2	4
19	75	78.6	65	69.4	7	8
20	65	66.5	55	59.0	2	3
21	65	70.4	55	63.2	2	3
22	65	71.1	55	65.0	2	3
23	75	78.7	65	69.0	7	8
24	75	79.0	65	66.9	7	10
25	75	80.0	65	69.0	7	10
26	65	70.0	55	64.2	2	2
27	70	73.6	60	66.3	3	4
28	70	74.0	60	65.3	3	3
29	70	75.2	60	68.4	3	3
30	70	73.9	60	65.2	3	4
31	75	78.4	65	67.2	7	8
32	75	81.1	65	71.1	7	10
33	65	70.0	55	64.4	2	2
34	70	71.7	60	63.6	3	3
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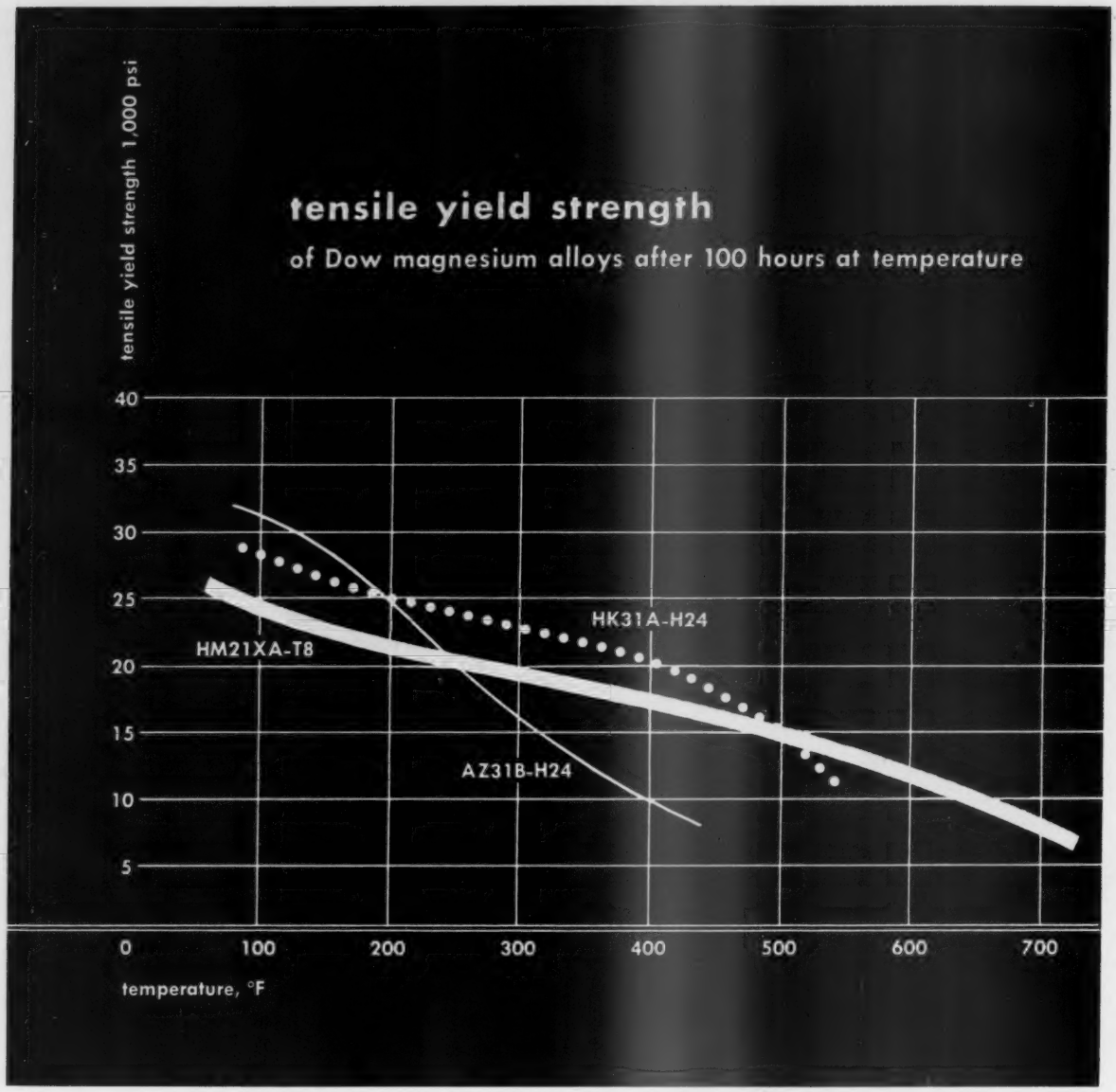

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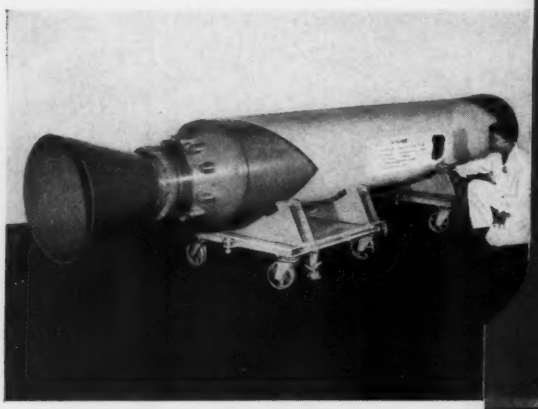

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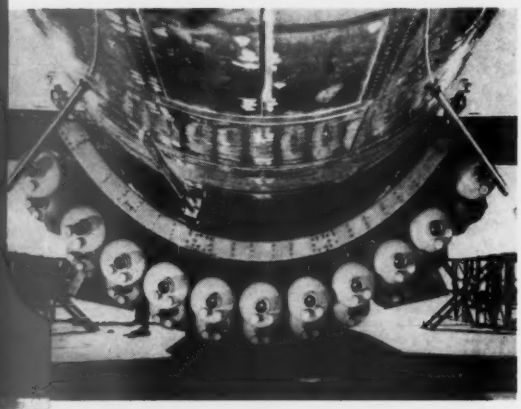

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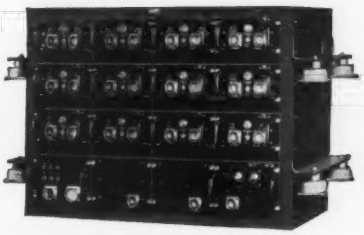

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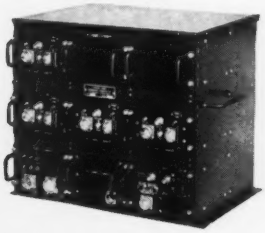

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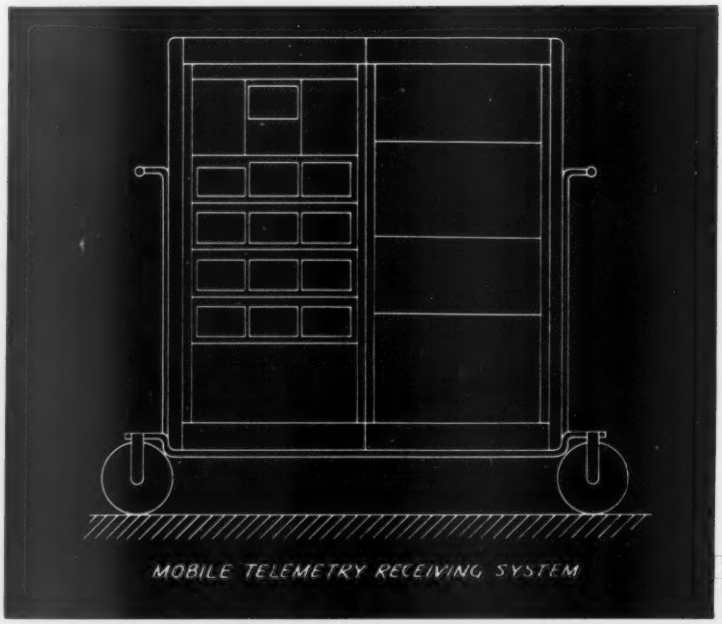

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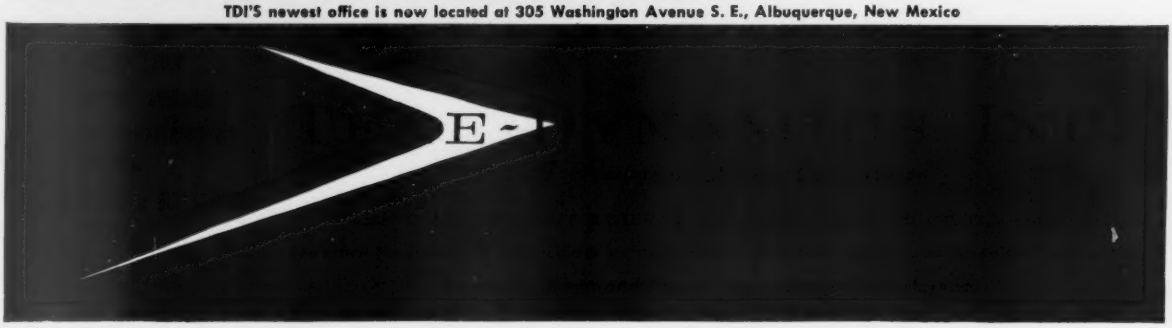

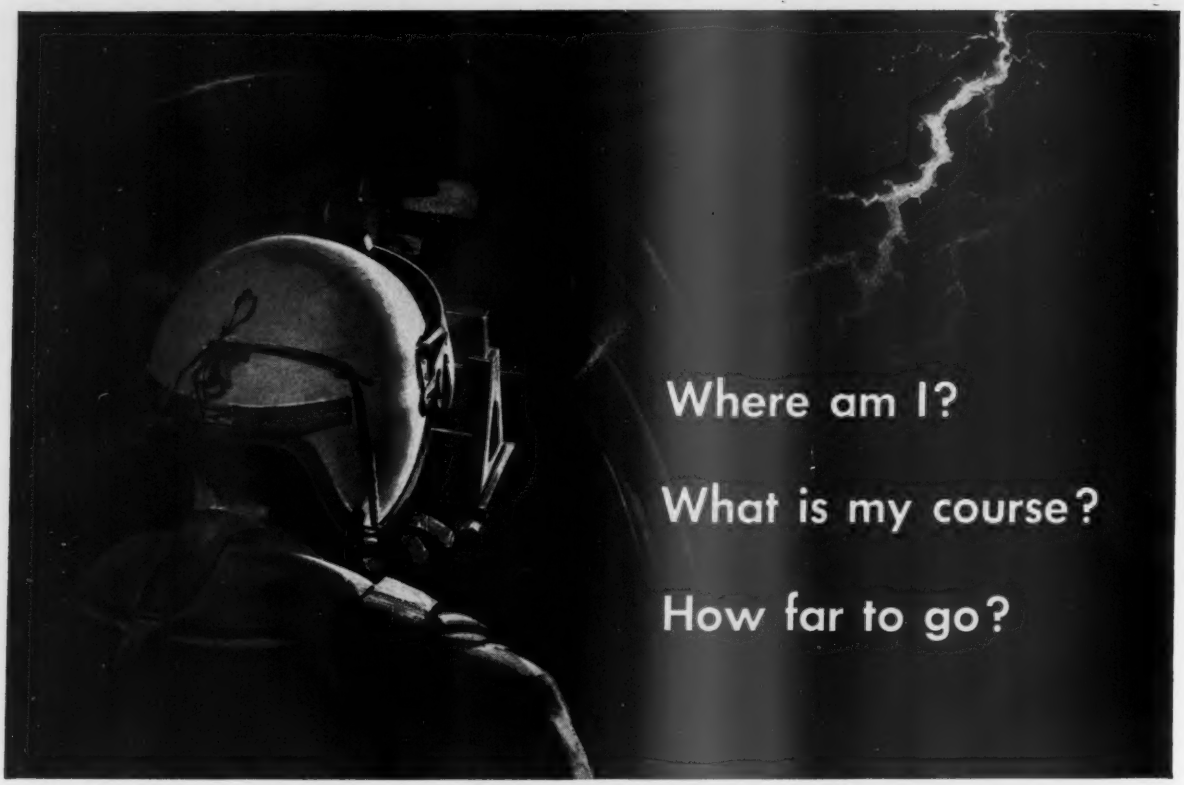

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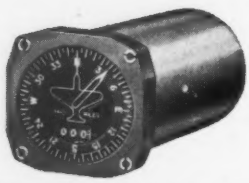

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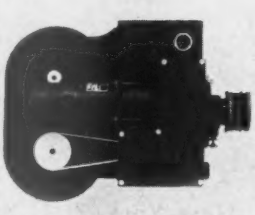

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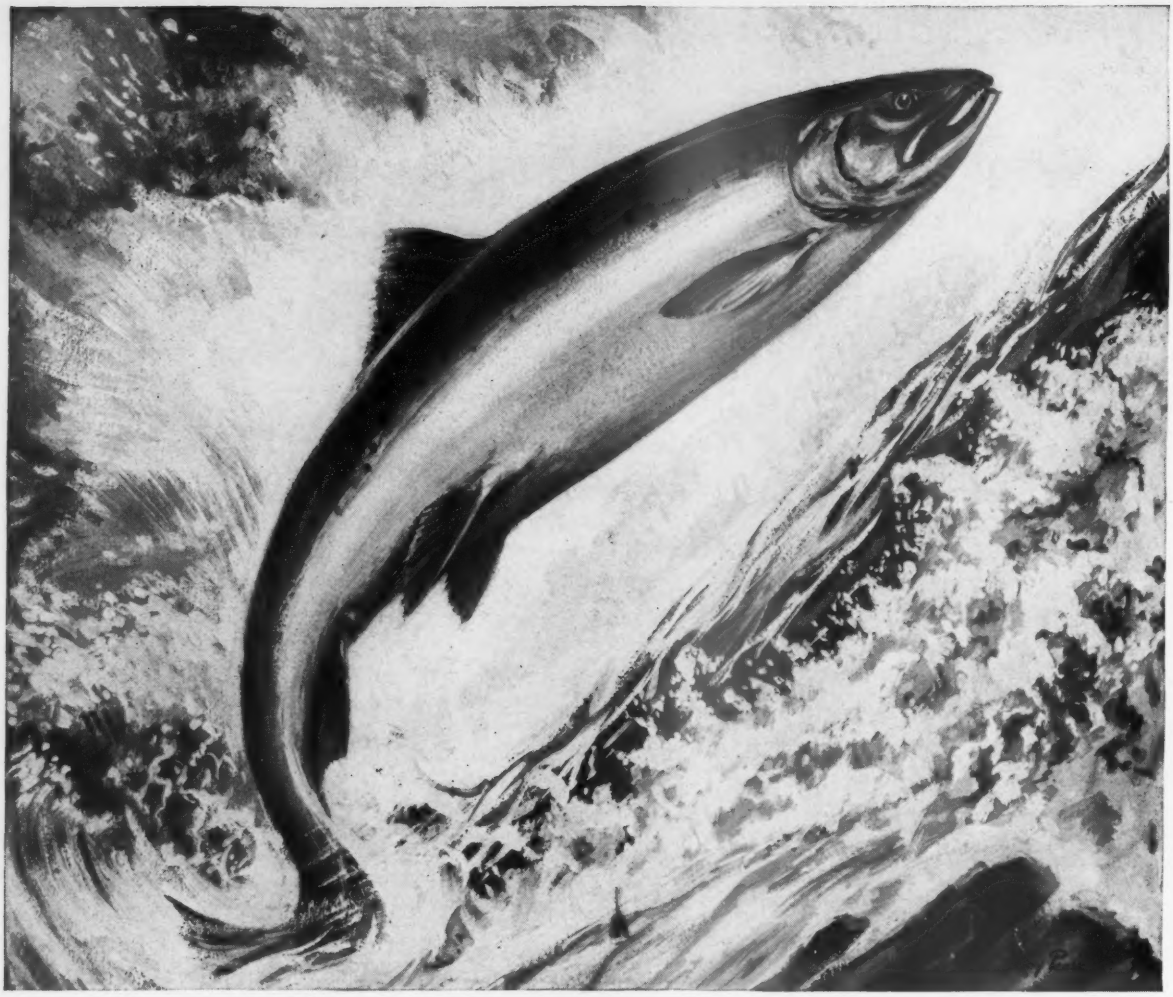

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Patrick Air Force Base
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Holloman Air Development Center
Alamogordo, New Mexico

AGE:
15 years in missiles; 37 in aircraft.

EDUCATION:
An engineering company managed by engineers — such as Donald W. Douglas, B.S., Aeronautical Engineering (M.I.T.); F.W. Conant, B.S., Civil Engineering (Cornell); and A. E. Raymond, B.S., Mechanical Engineering (Harvard), M.S., Aeronautical Engineering (M.I.T.), and Ph.D. (Hon.) (Polytechnic Institute of Brooklyn) — and with key staff positions held by graduate engineers, physicists and mathematicians, many with advanced degrees.

EXPERIENCE:
Pioneers in missile research development and production since 1941.

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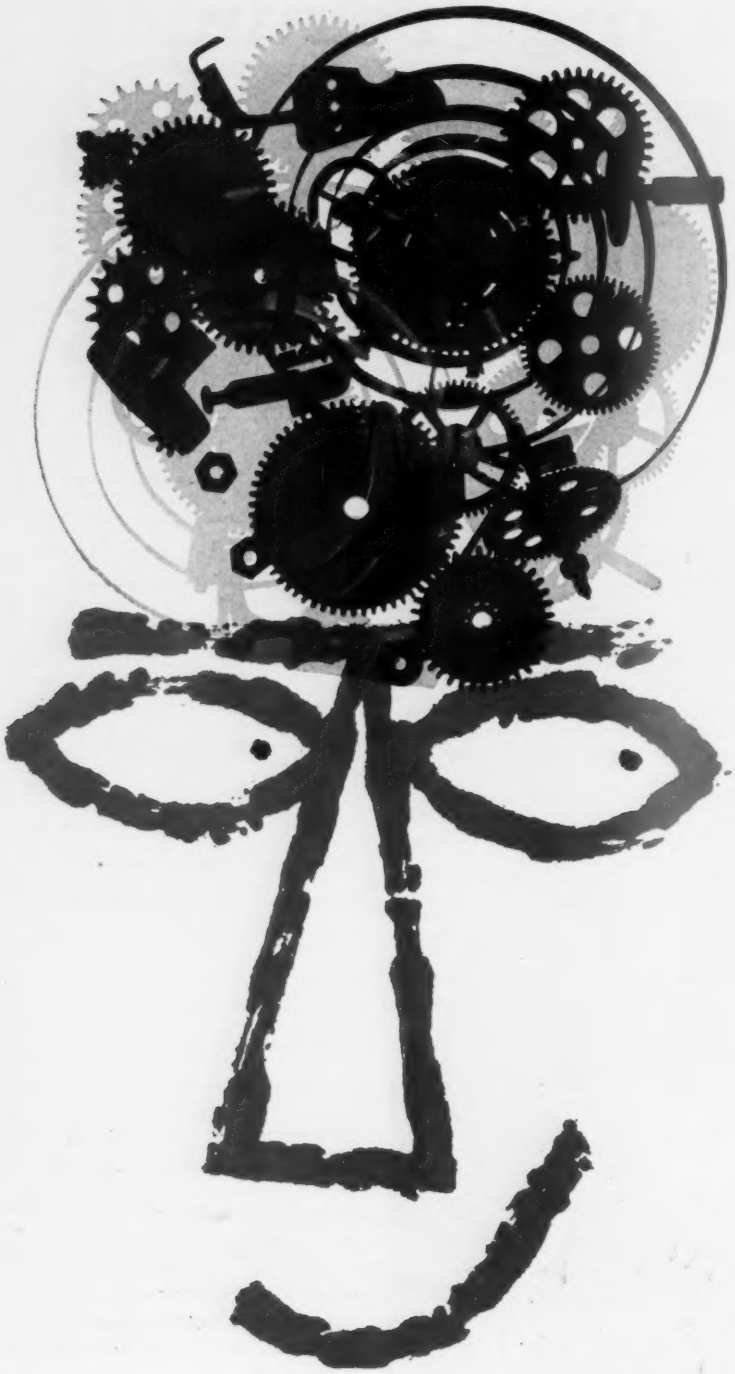

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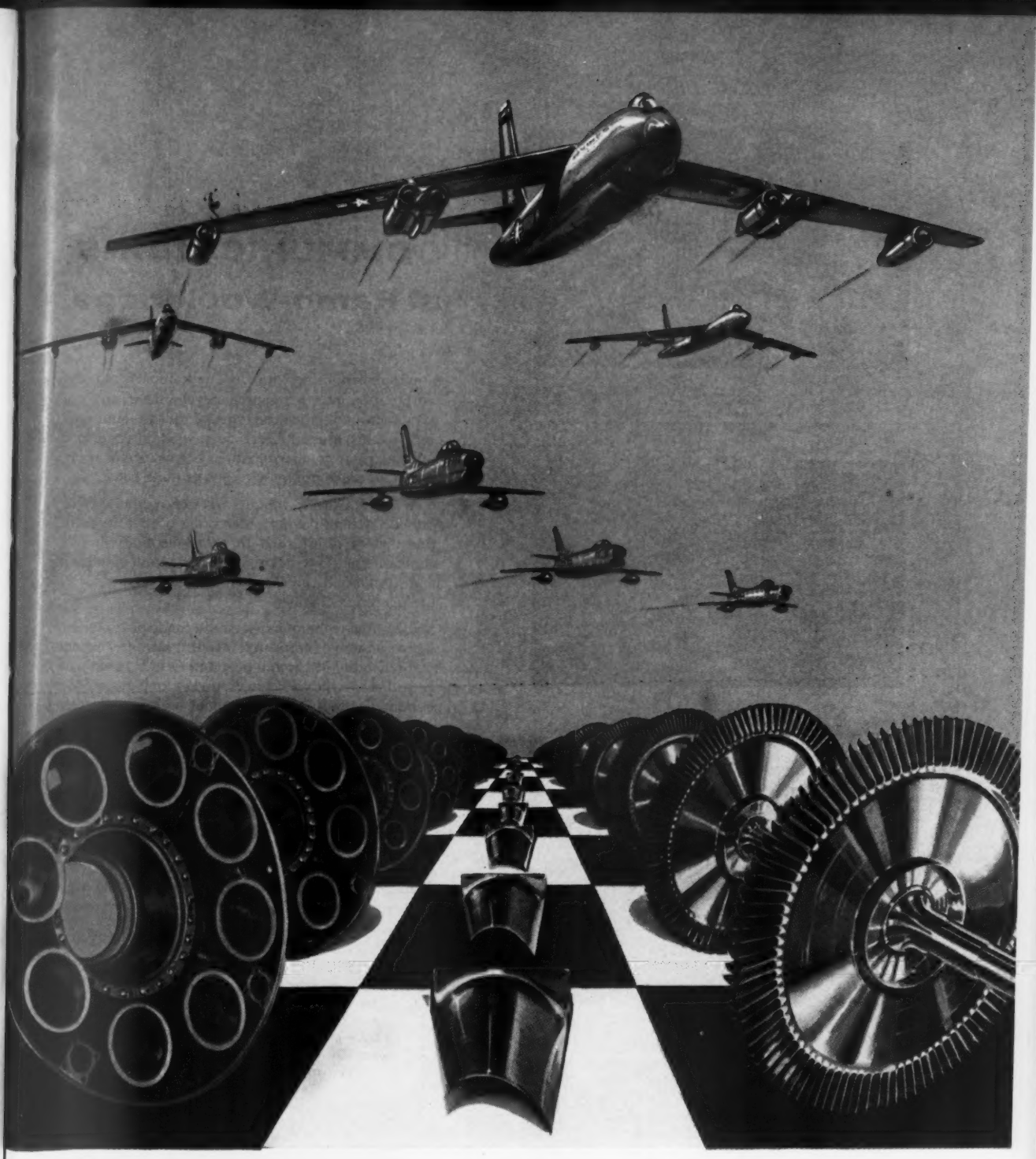

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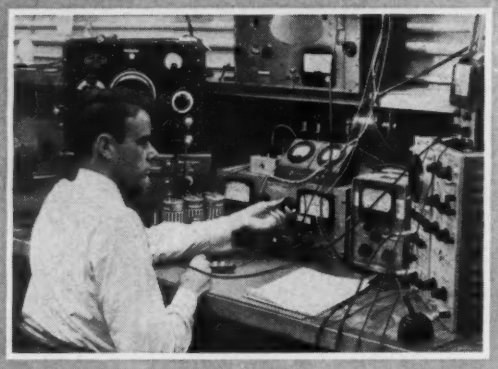

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MARCH 1957

VOLUME 27 NUMBER 3

JET PROPULSION
Journal of the
AMERICAN ROCKET SOCIETY

Editor-in-Chief

MARTIN SUMMERFIELD

The High Altitude Sounding Rocket

HOMER E. NEWELL, JR.[1]

Naval Research Laboratory, Washington, D. C.

The essential feature of a sounding rocket is its ability to carry scientific instruments into the upper atmosphere. Because of this, such things as solar radiation, radio frequency waves, the ionosphere, the earth's magnetic field, the composition of the atmosphere, the aurora, cosmic rays, micrometeorites, cosmic dust, atmospheric structure, winds, and airglow can be studied from a vantage point above the atmosphere. Because of the absorbing and obscuring effect of the atmosphere many of these observations can be made only from rockets. There are needs for rockets to carry instruments to peak altitudes ranging from 20 to over 200 miles. Payload requirements vary from less than 25 to more than 200 lb depending on the complexity and nature of the experiment to be performed. Operational simplicity, attitude controllability, cleanness, moderate accelerations, recoverability, and reasonable costs are all desirable features for a high altitude sounding vehicle. Rockets currently in use for upper air explorations are: Aerobee, Deacon, Cajun, ASP, Nike-Deacon, Nike-Cajun, Rockoon, Veronique, and Monica. A number of others are under development.

Introduction

OUR age has found many uses for rockets, one of which is to explore the outer reaches of the atmosphere. Soaring to altitudes far above those reached by other means, the rocket approaches and someday will enter the realms of outer space. Rocket-borne equipment can be put in direct contact with the upper atmosphere, the ionosphere, primary cosmic or auroral particles, and incoming micrometeorites, and can look directly at radiation from the sun and outer space without interference by the air. In fact, there are many observations which at present can be made only from rockets. Some of these are:

Ultraviolet light; x-rays from the sun, stars, and outer space
Radio frequency waves from the sun, stars, and outer space in the wavelengths cut off by the ionosphere
Ionospheric currents
Earth's magnetic field at high altitude
Chemical and ion composition of upper atmosphere
Auroral particles
Low energy cosmic rays
Micrometeorites
Dust in space

Also, there are many quantities that can be measured both in rockets and from the ground. Some of these are:

Atmospheric pressures, temperatures, and densities
Winds
Ionospheric charge densities
Airglow
Auroral radiations

To measure the first group of quantities a rocket vehicle is essential. For the second group, the rocket provides a means of checking by direct observation the ofttimes very indirect measurements made from the ground. With such rocket observations it is possible to calibrate the ground based techniques, thereby eliminating what have sometimes proved to be rather large systematic errors.

The essential feature of a sounding rocket is its ability to carry scientific instruments into the upper atmosphere. Nevertheless, other features that a given rocket may possess may be extremely important in determining its usefulness, and it is tempting to speculate on what properties an ideal sounding rocket should have. One soon concludes, however, that it would not be practicable to attempt to create a single rocket that is ideal for all high altitude research uses. Nevertheless, a list of some of the important features one would demand in such an ideal rocket can be of use in evaluating the potentialities of a specific rocket for high altitude sounding. The purpose of this paper is to present a partial review of such features.

Altitude Performance

At the present time there is an interest in performing experiments at altitudes ranging from 20 miles to over 200 miles. The field of upper air rocket research currently extends throughout this entire range, from the bottom where meteorologists are interested in determining atmospheric structure and winds, and in monitoring the sun's radiation in the near ultraviolet wavelengths, to the top where ionosphericists are especially interested in studying the upper reaches of the ionosphere, and cosmic physicists desire an unobstructed look into outer space.

To meet all of these needs calls for a variety of rockets. It would generally be uneconomical and unreasonable to attempt to perform the low altitude experiments in superperformance rockets, and of course it would be impossible to do the extreme altitude work in low altitude rockets. Moreover, since a vertically launched rocket spends a considerable portion of its flight time in the vicinity of its peak altitude, it is often highly desirable to have the peak of flight come just above the principal region of study.

Payload Capacity

In the past ten years, the United States has acquired a wealth of experience in instrumenting high altitude research rockets. As a result, the 150-lb nominal payload of the Aerobee is adequate for quite elaborate experiments. Few rocket experiments now require more than 200 lb, and in most cases 100 lb total is regarded as ample. In fact, a surprising amount can be done with the 25- to 50-lb loads carried by some of the smaller rockets like the Deacon. Finally, use in the future of transistors, magnetic cores, and special power supplies promises further substantial reductions in research rocket payload requirements.

Presented at the ARS 11th Annual Meeting, New York, N. Y., Nov. 26–29, 1956.

[1] Superintendent, Atmosphere and Astrophysics Division. Mem. ARS.

Experience in the early days of upper atmosphere sounding has shown that too large a payload capacity can have a bad effect. In such a case, the tendency is to use the entire capacity by including a variety of experiments. This often results in the different experiments interfering with and compromising each other to some extent. Also, the increased complexity of a multiple installation increases the chance of complete or partial failure. The most effective arrangement is to devote a given rocket to a single experimental objective.

Operational Simplicity

When the U. S. rocket upper air research program began ten years ago, the liquid propellant rocket held out the greatest promise for developing a high altitude sounding vehicle. Hence the Viking and Aerobee developments were undertaken. The liquid rocket, however, even at its simplest, is a complicated gadget. Both the Viking and the Aerobee require special launching facilities plus something like the White Sands complex for their most effective use, and this greatly restricts the amount of traveling one can do with these rockets. Although both the Viking and the Aerobee have been fired at sea, the operations were complex, difficult, and costly. Setting up for Aerobee firings at Fort Churchill, for the International Geophysical Year, has cost many millions of dollars, and has been a very complicated operation. Hence, one cannot plan on using such rockets for any great geographic extension of upper air sounding activities.

The only real hope for extending the geographic coverage of the rocket sounding program lies in the use of rockets that are operationally so simple that they can be set up and fired at remote locations with reasonable costs and reasonable engineering, logistic, and operational support. At the present time, only the solid propellant rockets offer real promise of filling this need. Already the solid propellant Deacon launched from Skyhook balloons has made it possible to carry out numerous upper air experiments in the arctic and in the Pacific. Such mobility should also be possible with Nike-booster launched Deacons or Cajuns. And in the not-too-distant future one may have solid propellant vehicles, comparable in altitude and payload capabilities to the Aerobee-Hi, that can be carried to remote locations for special studies.

Guidance and Control

As a general rule, the only guidance that a high altitude sounding rocket requires is that needed to project it in an essentially vertical trajectory and to land it somewhere within a rather extensive firing range. The latter is an obvious safety requirement, and is also a means of facilitating recovery of equipment or specimens from the fallen rocket.

Accurate attitude control, on the other hand, is often highly desirable. For many experiments it is important to maintain the axis of the rocket within a certain angle of a special direction in space, as the direction from the rocket to the sun, for example. In other cases, it may be important to generate a certain angle of attack or to give the rocket a prescribed spin rate, as in certain aerodynamic and atmospheric structure measurements. Thus the ability to control a sounding rocket in roll, pitch, and yaw can be a valuable asset.

The potential value to some experiments of being able to control the attitude of a rocket does not, however, necessarily mean that such control should be built into all sounding rockets. Such a procedure is expensive and necessarily uses up some of the payload capacity of the rocket. If the control feature is built in, then this payload penalty is imposed on all experiments for which the rocket is used, whether they require the control or not. One should consider the advisability of building the control feature into the experimental equipment itself, as in the case of a sunfollower mounting for a solar spectrograph, at the same time minimizing erratic behavior of the vehicle by careful alignment of the motor, fins, etc.

Cleanness

Just as a general principle the sounding rocket should not contaminate the atmosphere around it. Any gases entering the atmosphere from the rocket surface, instrument compartment, or motor may well interfere with or even vitiate the intended observations. This is especially true in the case of measurements of conditions in the vicinity of the rocket, such as local pressures, densities, composition, and ionization. In the case of observations over a long path outward from the rocket, as with the measurement of solar radiations, incoming cosmic or auroral particles, or total ozone between the rocket and the sun, the effect is probably usually negligible.

Although one cannot completely eliminate outgassing from the sounding rocket into the outer atmosphere, it is still well worth the effort to minimize the effect by such things as O-ring sealing of the instrument compartments and the propellant tanks, sealing off the motor after burnout in the case of liquid propellant vehicles, and eliminating gassy coatings on the rocket surface, even to the extent of leaving the rocket unpainted in special cases.

Moderate Accelerations

Low or moderate accelerations, that is, less than 10 g or so, are certainly desirable, since they impose no especially difficult mechanical design problems. One is, however, not restricted to such accelerations. It is certainly possible, with adequate care and thought, to design for much higher accelerations, and this has been done quite successfully for such vehicles as the Deacon and the Cajun in which the accelerations go as high as 75 g. One could even accept higher accelerations than those of the Deacon and Cajun, but no one would like this. Doubtless, when all other things are equal, of two rockets, the one having lower acceleration would usually be chosen.

Recoverability

The high altitude sounding rocket is really only one component in a complete system designed to obtain scientific information from the region of the upper atmosphere. Much of this information can be telemetered by radio means, but some of it is best obtained through the use of photographic films and the exposure of specimens. The latter approach requires the recovery of the film or specimen after the rocket flight. For such experiments a rocket which can be recovered either in toto or in part is needed. A rocket which could be recovered in condition to be reused would permit a most welcome saving in costs.

Costs

The cost of a sounding rocket is an important item to consider. A large and complex rocket like the Viking is so expensive that its use is limited to agencies like the Department of Defense, and even in this case it has been found too expensive for further use in normal upper atmosphere sounding. The Aerobee, including booster, propellants, servicing and launching charges, and recovery parachutes, costs between $30,000 and $40,000 per rocket, which is something like an order of magnitude less than the Viking. Thus, for the cost of one Viking a large number of Aerobee firings can be made, permitting either the repetition of a single experiment on many separate flights, or the separate performance of a number of different experiments, as desired.

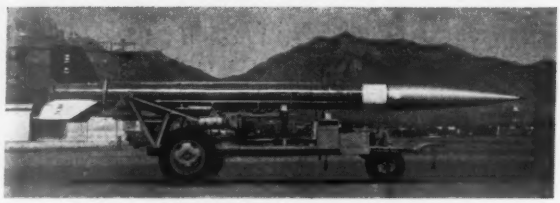
Even the Aerobee cost, however, is too great for most private institutions, and a serious effort should be made to bring prices down. It is hoped that the Iris rocket, the solid propellant counterpart of the Aerobee now under development, will be considerably less expensive than the Aerobee. This,

(*Continued on page 288*)

Aerobee-Hi Development Program

JOHN W. TOWNSEND, JR.[1] and ROBERT M. SLAVIN[2]

Naval Research Laboratory, Washington 25, D. C. Air Force Cambridge Research Center, Bedford, Mass.



Aerobee-Hi rocket mounted on trailer

The Aerobee rocket has been extensively used in the past as a vehicle for upper air research. Newer versions of this rocket, especially designed for this type of experimentation will be used in the forthcoming International Geophysical Year program. One model, designated as the Air Force Aerobee-Hi, will be capable of carrying a 150-lb payload to approximately 150 miles. The other model, designated the Navy Aerobee-Hi, will carry a 150-lb payload to approximately 170 miles. Both rockets are described in detail.

Introduction

THE standard Aerobee rocket designed and developed by the Applied Physics Laboratory of The Johns Hopkins University, and Aerojet-General Corp., under Navy sponsorship, has been extensively used by almost all agencies participating in upper air research with rockets. Aerobee, in over 200 flights, has proved itself a simple, reliable, and relatively inexpensive rocket, capable of carrying a 150-lb payload into the E-region of the ionosphere (70 miles).

The rocket itself has been well described in the literature. It is a fin-stabilized, liquid propellant rocket using red fuming nitric acid as the oxidizer and a mixture of aniline and furfuryl alcohol as the fuel. The thrust chamber is regeneratively cooled and the tanks are pressurized via a regulator with high pressure helium. The vehicle is 15 in. in diam and 18 ft long. In order to minimize impact dispersion due to winds, the vehicle is boosted and is launched from a tower approximately 150 ft high. Both rocket and booster have three fins.

The original design and development was begun in 1946. The program led to the 2600-lb thrust RTV-N-10, RTV-A-1, and XASR-SC-2 Aerobee rockets used by the Navy, the Air Force, and the Signal Corps, respectively. In 1949 the Air Force initiated the design and development of a 4000-lb-thrust Aerobee rocket. This Aerobee has been used by the Air Force, with the designation RTV-A-1a, and by the Navy, with the designation RTV-N-10a.

In 1952 the Air Force and the Navy were approached by the Aerojet-General Corp. concerning the possibility of developing a further improved Aerobee rocket. Contracts for the improved Aerobee, designated Aerobee-Hi by both services, were let in 1952 by the Air Force and in 1953 by the Navy. In the case of both services, the intent was to develop a rocket expressly designed to suit the needs of the upper air physicist who uses the rocket as a high altitude observatory. This implied, then, that the rocket was to be designed with certain specific goals in mind and not with the idea of going as high as possible above the earth's surface.

Although the Navy Aerobee-Hi and the Air Force Aerobee-Hi differ in detail, the two services have maintained coordinated, complementary development programs that have common objectives. The results of the research and development on either program have been useful to the other.

All Aerobees and Aerobee-Hi's are designed and built by Aerojet-General Corp. at Azusa, Calif.

Air Force Program

In 1952, the Air Force negotiated a contract with Aerojet-General Corp. to improve the performance of the RTV-A-1a Aerobee. The design aim was to carry 150 lb of payload to altitudes of about 150 miles.

To reach this aim, two approaches were used, directed at improving the mass ratio of the rocket. These were:

1 The extension of the fuel and oxidizer tanks to include 32 per cent more propellants.

2 The fabrication of tanks from the lighter type 410 stainless steel.

The result of these changes was an improvement of vehicle mass ratio from 3.17 to 4.62. Table 1 presents a comparison between the original Aerobee and the current Air Force Aerobee-Hi.

Wind tunnel tests and aerodynamic studies were under-

Table 1 Specifications for Air Force Aerobee and Aerobee-Hi

	Model AJ10-25	Model AJ11-6
Length of vehicle, less extensions	227 in.	251 in.
Length of booster	79 in.	79 in.
Diameter	15 in.	15 in.
Payload volume	6 ft³	6 ft³
Payload weight	120 to 200 lb	120 to 200 lb
Dry weight	300 lb	234 lb
Oxidizer weight	497 lb	641 lb
Fuel weight	181 lb	247 lb
Helium weight	5 lb	6 lb
Thrust of sustainer	4,000 lb	4,100 lb
Thrust of booster	18,000 lb	18,000 lb
Duration of sustainer	34 sec	42 sec
Duration of booster	2.5 sec	2.5 sec
Specific impulse of sustainer (sea level)	193 sec	198 sec
Burnout altitude, 120-lb payload	80,000 ft	122,500 ft
Burnout velocity, 120-lb payload	4,880 fps	6,770 fps
Summit altitude,[1] 120-lb payload	80 miles	165 miles
Burnout altitude, 200-lb payload	74,000 ft	111,500 ft
Burnout velocity, 200-lb payload	4,300 fps	5,860 fps
Summit altitude,[1] 200-lb payload	66 miles	122 miles

[1] Launching at the Air Force rocket range in New Mexico.

Presented at the ARS 11th Annual Meeting, New York, N. Y., Nov. 26–29, 1956.

[1] Head, Rocket Sonde Branch, Naval Research Laboratory.

[2] Geophysics Research Directorate.

taken to determine stability and wind-weighting factors, and flights of the X-8a with elongated tanks (later known as the AJ10-34) were carried out by the Navy and Air Force to prove the dynamic stability of the new configuration. Difficulties were encountered in welding the type 410 stainless steel tanks but these were eventually overcome.

The first flight of the new model occurred in April of 1955 and was a complete success. An overweight payload of 196 lb was carried to the predicted altitude of 123 miles. On the second and third Air Force rounds, instability during the burning period resulted in unsatisfactory performance. The use of acid with high NO_2 content caused thrust chamber burnout on these flights.

Two more flights are scheduled this year to gain further performance information on this model. Success on these flights will result in the use of this model as one of the Air Force research vehicles.

Navy Program

The Navy Aerobee-Hi program was begun with the overall objective of developing a comparatively inexpensive and reliable sounding rocket specifically designed to meet the needs of the upper air physicist and able to carry a 150-lb payload into the F-region of the ionosphere (180 miles). The requirement that the rocket meet the needs of the experimental groups resulted in a specification that the rocket, including thrust chamber, be completely pressure sealed to eliminate, to a large degree, the problem of gas escaping from the rocket and interfering with the measurement of ambient conditions in the upper air at high altitudes. It was decided that, if necessary, altitude was to be sacrificed in order to accomplish reduction of the rocket-gas problem, increase reliability, or make the rocket less complex and easier to handle.

The Air Force, as previously described, had already begun the development of the lighter propellant tanks. In order to meet the higher altitude requirement for the Navy it was decided to increase further the propellant capacity of the vehicle, to improve the thrust chamber, and to increase the mass ratio by the incorporation of a chemical gas generator to replace the helium storage tank. In addition, the Navy sponsored the complete design change necessary to effect the sealing of the rocket to eliminate outgassing.

Two other programs were carried out in support of the main effort. The first of these was the design, but not development, of an attitude control system for the rocket. The second was a program of hypersonic wind tunnel tests to extend the range of the work done by the Air Force to include Mach numbers which the Navy rocket was expected to achieve.

Several models of the rocket, all known as the Navy Aerobee-Hi, have been flown during the past two years as a result of the development effort. In general the results have been satisfactory but there have been setbacks in several areas in which progress was hoped for.

The program to increase the propellant capacity of the rocket has been completely successful. To insure stability of the rocket at high burnout altitudes, new larger fins were designed that appear to serve the purpose well.

The effort made in connection with improving the thrust chamber has not been successful to date, although work is still in progress. A more efficient and lighter thrust chamber was developed and flown, but problems of inner liner failure led to dropping the new chamber in current models. As a result of the thrust chamber program, however, it was found that performance of the thrust chamber was a critical function of water content in the acid. These data have led to a new specification for low water content acid, the use of which will improve the performance of any Aerobee model.

The development of the chemical pressurization system never received a fair test. In two flight tests other failures in the rocket system prevented evaluation of the solid propellant hot gas generator. Unfortunately, due to lack of money, and due to lack of time caused by the necessity for producing Aerobee-Hi rockets for the forthcoming International Geophysical Year, the development effort has been indefinitely suspended and current models of the Navy Aerobee-Hi still carry helium pressurization.

The design and development of the pressure seal feature has been completely successful. All models of the Navy Aerobee-Hi are well sealed by the use of O-rings at all joints and at points where breaks in the skin are made for electrical plugs, pressurizing lines, etc. The thrust chamber is sealed at burnout by the use of two pyrotechnic propellant shutoff valves. It has been found that, with proper attention, the nose and tail cones can be left overnight, pressurized with 15 lb per sq in. of helium, without the loss of more than 1 lb per sq in. by the next morning.

The two supporting programs have been of benefit to the over-all effort. An attitude control system has been designed that appears to be practicable. Hypersonic tests have been run, and aerodynamic coefficients determined over the range Mach 3.0 to Mach 6.3.

To date, seven rockets have been flown in the Navy Aerobee-Hi program:

(a) A text rocket, Model RTV-N-10b, was flown in October 1954. The rocket was a standard RTV-N-10b, with more propellant and a different mixture ratio. The flight was good and an altitude of 98 miles was achieved. The production version of this rocket, RTV-N-10c, has been flown over ten times with excellent results. This Aerobee is now the new "standard" Aerobee for the Air Force and Navy.

(b) Aerobee-Hi, XRV-N-13, was flown twice in 1955. This model contained the hot gas pressurization, improved thrust chamber, lighter tanks, more propellant, and the new tail fins. Both rockets were total failures. The first, NRL-37, failed to ignite due to faulty regulator system design. The second, NRL-38, suffered a hard start and exploded just after leaving the tower. The failure was attributed to a too abrupt starting phase complicated by low temperature.

(c) Aerobee-Hi, RV-N-13a, was flown three times in 1956. This model did not contain the hot gas pressurizing system, but did have all the other Aerobee-Hi features including the improved and lighter thrust chamber. It contained even more propellant than the XRV-N-13. The first rocket, NRL-39, did not ignite due to a failure in the range safety

Table 2 Specifications for Navy Aerobee-Hi Model RV-N-13b

Length of vehicle, less extensions	283.4 in.
Length of booster	78.6 in.
Diameter	15.0 in.
Payload volume	6 ft³
Payload weight	120 to 200 lb
Dry weight	269 lb
Oxidizer weight	745 lb
Fuel weight[1]	313 lb
Helium weight	7 lb
Thrust of sustainer	4,100 lb
Thrust of booster	18,000 lb
Duration of sustainer	50 sec
Duration of booster	2.5 sec
Specific impulse of sustainer (sea level)	198 sec
Burnout altitude, 120-lb payload	131,000 ft
Burnout velocity, 120-lb payload	6,650 ft
Summit altitude,[2] 120-lb payload	165 miles
Burnout altitude, 200-lb payload	118,000 ft
Burnout velocity, 200-lb payload	5,750 fps
Summit altitude,[2] 200-lb payload	122 miles

[1] 23 lb of fuel remains unused in this model at burnout.
[2] Sea level launch, arctic atmosphere.

circuits and the rocket was a total loss. The second, NRL-42, reached a peak altitude of 117 miles. There was a thrust chamber inner liner failure at 45 sec which prevented the rocket from reaching its predicted altitude of 190 miles. The third, NRL-46, also burned out early due to thrust chamber failure and only reached an altitude of 43 miles.

(d) Aerobee-Hi, RV-N-13b, has been flown once in 1956. This model employs the standard 4000-lb-thrust Aerobee chamber instead of the Aerobee-Hi chamber. The single flight, NRL-50, was a complete success, reaching a peak of 164 miles with a 145-lb payload. This rocket set a new altitude record for American-built boosted rockets, and also demonstrated that high burnout altitudes are feasible with fin stabilized rockets.

The Navy Aerobee-Hi program is not complete at the date of this report. It is felt that future models of the rocket will reach 200 miles with a 120-lb payload and that the final model, to be used during the IGY, will meet all of the specifications set for it by the needs of the upper air research groups. Table 2 sets forth the principal specifications for the model RV-N-13b Aerobee-Hi rocket and Table 3 lists its principal features.

Table 3 Distinctive features of Navy Aerobee-Hi Model RV-N-13b

Rocket section	Feature	Purpose
Nose	61S-T6 0.049-in. aluminum spinning	reduce effects of aerodynamic heating
	O-ringed seal at tip	pressurization
Extensions	magnesium	save weight
	10-in. camera extension	
	15-in. standard extension	
	nose recovery parachute system	
	body recovery parachute system	
Forward skirt	magnesium	save weight
	Nike regulator with overboard dump	reliability, safety, performance, cost
	new delayed start ignition system	reliability
	completely pressure sealed, all trip devices go through O-rings	pressurization
	fast acting trip	reliability
Propellant tanks	410 stainless teel	save weight
	more propellant	increase altitude
After skirt	magnesium	save weight
Tail cylinder	magnesium	save weight
	O-ring sealed	pressurization
	propellant shutoff valves	pressurization
Fins	magnesium	save weight
	bigger area	improve aerodynamics
	more rigid	improve aerodynamics
	built in notch antennas	save weight, convenience
Booster	new attachment rings	more rigid coupling with cylindrical tail

Conclusions

At the present time both the Air Force and the Navy programs are nearing the end of the development stage. However, models flown after the fall of 1956 will incorporate final improvements which are expected to increase performance significantly without decreasing reliability.

The current Air Force rocket, Model AJ-11-6, can carry the standard payload of 150 lb to an altitude of 140 miles above sea level assuming a launch at sea level and an arctic atmosphere. For a launching at White Sands Proving Ground, New Mexico, the peak altitude is increased by about 15 miles. The current Navy rocket, Model RV-N-13b, can carry the standard payload of 150 lb to an altitude of 147 miles above sea level under the same conditions. Again, launching at WSPG increases the altitude by about 15 miles. In both cases, going to a minimum payload of 120 lb will increase the altitude by about 17 miles under the arctic atmosphere, sea level launch conditions.

In the case of the current Navy Aerobee-Hi, a simple change in the tanks, which will be made on all future models, will increase the altitude by over 10 miles. The reason in this case is that the current tanks were built before a changeover in thrust chambers occurred, and the rocket as now being flown carries about 23 lb of excess fuel.

The final major change which probably will be made in both Aerobee-Hi's is the incorporation of a ceramic-lined thrust chamber to replace the current regeneratively cooled chamber. This 5000-lb-thrust unit is now being developed by the Aerojet-General Corp. Test pit static firings have been made and the unit appears to be ready for test flights this winter. A Navy Aerobee-Hi with this chamber is expected to reach an altitude of 167 miles with a 150-lb payload under arctic sea level launch conditions. The altitude with a 120-lb payload is 188 miles. Again, firing at WSPG will increase the altitude by about 15 miles. The increase in altitude for the Air Force model is similar.

Both services expect to fire Aerobee-Hi rockets in quantity at Fort Churchill, Canada, during the International Geophysical Year, July 1957 to December 1958. The rockets will carry experiments designed to study the arctic upper atmosphere in detail. Fort Churchill was selected because it is an arctic site in the auroral belt and because of good transportation.

Final mention should be made of expected reliability for the Aerobee-Hi rocket because of its utmost importance to the instrumenting groups involved in rocket research. There are, of course, at this date no meaningful statistics which reveal what reliability can be expected of Aerobee-Hi, but it can be stated that the reliability should be high since the rocket is simple and since the design is based on an extension of a design which has been tested in about 200 standard Aerobee flights. There have, of course, been failures in these firings, but more than three quarters of these failures have been on developmental and test flights.

Rockets

by ROBERT H. GODDARD

A limited number of copies of this "classic" in the field of jet propulsion literature is still available from the American Rocket Society, 500 Fifth Avenue, New York 36, N. Y.

$3.50

The Nike-Cajun Sounding Rocket

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The Nike-Cajun all solid propellant sounding rocket is a two-stage combination, using the Nike booster as first stage and the Cajun as the instrument-carrying second stage. When fired at 85 deg launching angle and with a 15-sec coast between stages, it has carried 50 lb to 100 miles altitude. Successful flights at Wallops Island, White Sands, Fort Churchill, and aboard ship have demonstrated that it is a simple and reliable sounding vehicle. It will be used during the IGY at Fort Churchill and at Guam. About 50 Nike-Cajuns will be instrumented to measure water-vapor distribution, the earth's magnetic field, cloud structure, pressure, temperature, density, winds, cosmic rays, and auroral particles.

THE V-2 rocket, which for six years was a mainstay in upper air research, appears in retrospect to have been a mixed blessing. With its 2000-lb payload, it gave an exaggerated ideal of what payload was necessary and desirable in a sounding rocket. The trend to smaller rockets started early with the development of the Aerobee and the use of the Deacon, but one wonders whether the delay was longer than necessary in making the transition from the 1-ton payload to the 50-lb, or even 10-lb, level. However that may be, small solid propellant rockets are now being embraced as an effective means of getting upper air data on a synoptic basis.

A big step in this direction was the development of the Rockoon combination by Van Allen in 1952. From these flights it was realized that instrumentation for upper air work could be tailored to 50 lb without extreme measures, that such instrumentation could easily withstand the 50- to 100-g accelerations of a fast-burning solid propellant vehicle, and that the handling and launching operations could be made simple enough to come within the capability of the scientific research team itself.

In certain applications, the Rockoon presents difficulties in tracking and impact location because of the time of ascent of the balloon and the drift during that time. A booster eliminates these difficulties and in 1954, after it had been decided that the Deacon was just right for a new upper air experiment being developed at Michigan for the Air Force, several boosters were investigated. It was learned that the Pilotless Aircraft Research Division of NACA at Langley Field was using the Nike-booster–Deacon-rocket combination for achieving high Mach numbers at medium altitudes. Calculations showed that with a steep firing angle and a coasting period between the two stages, the Nike-Deacon would carry 50 lb to perhaps 400,000 ft. Under the sponsorship of the Air Force Cambridge Research Center, the University of Michigan undertook a cooperative effort with NACA to try out a high altitude version of the Nike-Deacon.

Presented at the ARS 11th Annual Meeting, New York, N. Y., Nov. 26–29, 1956.

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[5] Chief, Guidance and Control Branch, Ballistic Research Laboratories.

At this point, acknowledgment is made of the debt to the Pilotless Aircraft Research Division of NACA, which combined the Nike and Deacon in the first place and which for the first two high altitude trials provided Deacons and couplings, Nike fin designs, and the use of their launching site, firing crew, and tracking facilities. NACA also specified the Cajun rocket (which is essentially a Deacon with a modern propellant, manufactured by the Thiokol Chemical Corp.) and provided many hours of consultation on problems of design, heating, and stability. At Michigan, the coasting trajectory was predicted and the second-stage fins and nose cones for the first flights were designed and built.

Two flights were carried out at the NACA site at Wallops Island, Va., in June 1955. The rockets performed successfully, reaching an altitude of approximately 348,000 ft. The instrumentation carried was the falling-sphere method for density (described below) and radar beacons for tracking. Following these firings, the University of Michigan purchased and assembled components for 12 Nike-Cajuns. Ten of these have been fired so far, all successfully—seven by Michigan, one by the New Mexico College of Agriculture and Mechanic Arts, and one by the Ballistic Research Laboratories.

The procurement of these Cajuns has brought out one disadvantage of the vehicle. It cannot be bought in one place, but must be purchased as parts and assembled by the user. When the user has done this, he will have spent about $4000 for each rocket, exclusive of the scientific instruments and the booster. If the latter is purchased, the cost is $3700 more. All of the boosters so far have been the gift of Army Ordnance.

A suitable criterion for a small sounding rocket might be that it can be completely man-handled. On this basis the Nike-Cajun is not small. It weighs about 1500 lb at takeoff and is 26 ft long. The launcher, which is a modified Nike launcher, is power operated and the booster is placed on the launcher with a small crane or fork lift. Neither of these items, however, implies a major installation; and the remainder of the equipment and operations are simple enough so that the scientific research group can carry them out by itself without extensive equipment. The biggest factor in the ease of handling is, of course, the solid propellant, which eliminates fueling, tanks, pumps, pressure checks, and a number of other things which make a trained firing crew necessary for launching a liquid rocket.

Fig. 1 shows Nike-Cajun No. 1, which was launched at Wallops Island in July 1956. Starting from the base of the booster, the essential mechanical features are:

1 The booster fins, which are of welded magnesium plate and casting construction, hinged together. Because the Cajun is considerably lighter than the Nike missile, the booster fins are subject to greater aerodynamic loads than those on a Nike. Therefore, they are smaller, stronger, and more rigid. Four are used instead of three to make up some of the loss in area.

2 The booster itself, which is used without modification.

3 The coupling, which is a cast magnesium cone with a cylindrical section on the forward end. The cylinder plugs

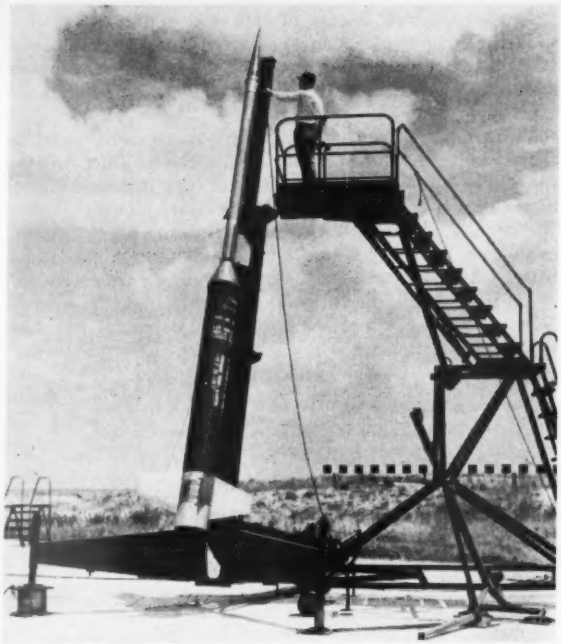

Fig. 1 Nike-Cajun No. 1 (fired at Wallops Island on July 6, 1956)

into the carbon throat of the Cajun, which separates from the booster at burnout by differential drag. The coupling bolts to the forward end of the booster.

4 The Cajun fins, which are made from extruded Dural and hinged together. These fins are probably the most difficult part of the design as they must be light, yet rigid under the heating encountered at Mach 6. They are provided with Inconel cuffs to prevent heat erosion of the leading edges just before burnout.

5 The Cajun bottle, which consists of a case, propellant grain, a threaded nozzle to which the fins are screwed, and a threaded head cap to which the instrumentation section is screwed.

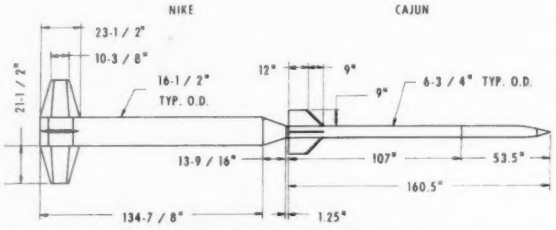

Fig. 2 Dimensions of Nike-Cajun

Fig. 2 shows most of the important dimensions. The gross takeoff weight is 1550 lb, and the gross weight of the Cajun at separation is about 250 lb. Fig. 3 gives the main features of the trajectory. A coasting period is essential to get the Cajun out of the high drag region before it reaches its peak velocity, but once this is allowed for, the peak altitude is not critically dependent on the coasting period. Somewhere between 10 and 20 sec is about right, but it must not be too long as the fins will then ineffectively maintain a stable flight.

An important development following the successful Nike-Deacons of two summers ago was that the various research agencies who planned the Aerobee installation at Fort Churchill expanded the plan to include the new rocket. A fully equipped launching site for Nike-Cajuns has been constructed at Churchill. A request to Army Ordnance for 65 boosters was granted. Forty-two of these will be fired at

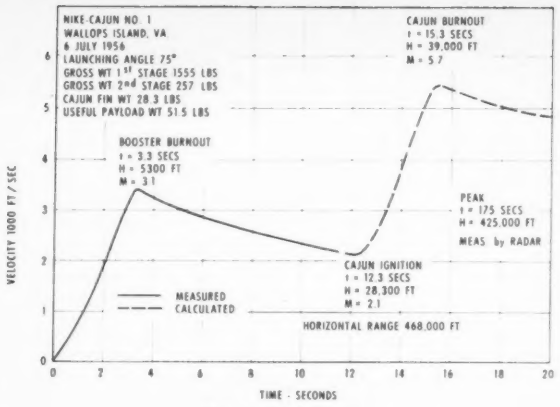

Fig. 3 Trajectory

Churchill during the International Geophysical Year, thus more than doubling the number of firings originally planned. The remainder will be fired from shipboard, at White Sands and at Guam.

The Ballistic Research Laboratories intend to fire ten Nike-Cajuns at Churchill and two at White Sands. In four of these rockets, the instrumentation will measure the quantitative and qualitative aspects of water-vapor distribition from 30 to 80 km. In three, a high precision total-field magnetometer will be flown to measure the jump in the magnetic field expected when the rocket passes through a current sheet predicted to flow in the E-region of the ionosphere. In these seven rockets, a determination of electron density distribution will be made for the E-region. The remaining five rockets will be instrumented to photograph the optical horizon, and so study arctic cloud structure and atmospheric striations which have been observed on earlier balloon flights in the southwest.

The question of whether or not there are substantial amounts of water vapor above 30 km is quite important for an understanding of atmospheric mixing and composition above the tropopause. The tropopause, with its low temperatures, should act as a barrier in the transport of tropospheric water vapor to higher altitudes. There are, however, indications of water vapor at high altitudes, such as noctilucent clouds and night-sky OH-bands, which emphasize a need for direct measurements.

Part of the variation in the geomagnetic field at the earth's surface has been explained in terms of a current sheet flowing in the E-region of the ionosphere. During magnetic storms, very high current densities are predicted for the E-layer at the lower boundary of the auroral zone. The BRL rockets with magnetometers will be fired into the E-layer during magnetic storms to measure the jump in magnetic field as the current sheet is traversed. This experiment, together with a determination of equivalent electron density, will give a measure of the flow rate of electrons in the E-layer. On August 9, 1956, BRL flew a Nike-Cajun at White Sands containing instrumentation for measuring rocket performance and trajectory. This rocket, carrying a payload of 60 lb, achieved a peak altitude of 100+ miles. Fig. 4 shows the layout of the instruments; all worked successfully throughout the flight.

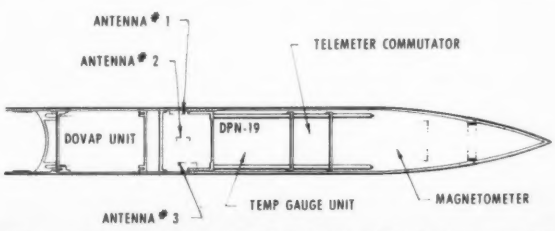

Fig. 4 Instrumentation layout of BRL flight of Aug. 9, 1956

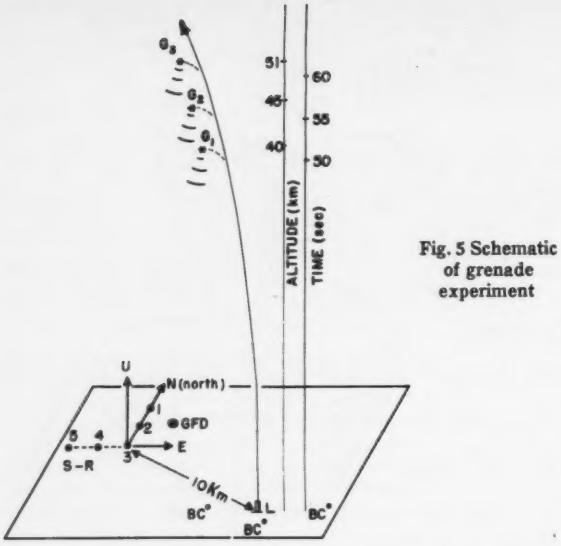

Fig. 5 Schematic of grenade experiment

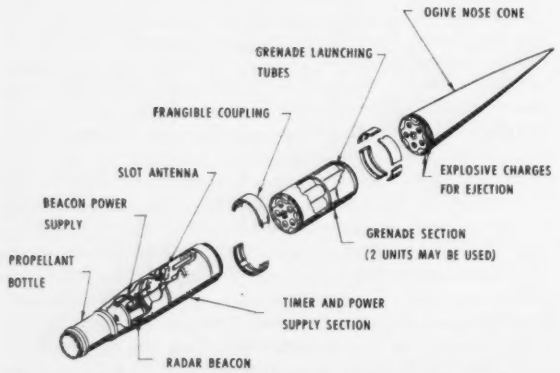

Fig. 6 Grenade instrumentation designed for Signal Corps Nike-Cajun

The Signal Corps Engineering Laboratories are applying the Nike-Cajun combination to the rocket-grenade experiment for the measurement of atmospheric temperatures and winds up to altitudes of 70 miles. The basic experiment, previously carried on the Aerobee rocket, is illustrated in Fig. 5. The explosive charges are ejected at regular intervals; and, by sound ranging from the ground, temperatures and winds in the layers defined by the grenades are determined.

The Cajun grenade instrumentation, shown in Fig. 6, consists of ten 4-lb grenades, in two Gatling gun-like structures, a jettisoned 15-caliber ogive nose cone, and S-band radar beacon, and timer and battery packs. The instrumentation is "oversized," being $8^1/_2$ in. in diam compared to the Cajun's $6^1/_2$. It is expected that the rocket combination will lift the 70-in-long 100-lb payload to about 70 miles. Ten of these rockets will be fired at Guam during the IGY.

The Signal Corps is also using the combination to test its planned satellite instrumentation for meteorological measurements. One unique feature of this rocket will be the nonconducting nose cone required by the fact that magnetic-field measurements are planned. The 30-caliber ogive topping a 42-in.-long instrumentation section weighing only 60 lb, is expected to permit top performance for the Nike-Cajun combination, i.e., over 100 miles peak altitude. The considerable aerodynamic heating expected has caused, and will continue to cause, difficult mechanical design problems. Present plans call for a $^1/_8$-in. wall of the 91LD phenolic-resin Fiberglas laminate for the ogive and cylinder to act solely as a wind shield.

Another planned feature of the vehicle will be the controlled introduction of spin of about 100 rpm by the use of tabs on the trailing edges of the Cajun fins. This problem has not been fully explored at this time, but is required by the experiment planned.

Two groups at the University of Michigan, both under the sponsorship of Air Force Cambridge Research Center, will use the Nike-Cajun during the IGY for the measurement of upper air pressure, density, and temperature. Twelve rockets will be instrumented with Alphatron pressure gages mounted in the nose cone. The Alphatron is an ionization gage which uses a radioactive rather than a thermal ionizing element. From the pressures measured at two points on the side of the cone, and impact pressure measured at the tip of the cone, both ambient pressure and Mach number of the missile may be calculated. Missile velocity is obtained from ground tracking and this, together with Mach number, permits the calculation of ambient temperature. The temperature can also be calculated from the ambient pressure, thus giving a check on the Mach number method.

This experiment was flown in a Nike-Cajun at White Sands in August 1956 and at Churchill in November. The instrumentation, which is seen in Fig. 7, weighs 90 lb and is serviced very readily by removing either one of two hinge pins, which run the length of the cylindrical section.

A second Michigan experiment measures upper air density by measuring the drag acceleration of a falling sphere. This is the experiment for which the Nike-Deacon and Nike-Cajun were originally developed as sounding rockets. It has been flown successfully twice at Wallops Island and five times during November aboard the U.S.S. *Rushmore* on a trip to Greenland. Preliminary indications are that the shipboard rockets exceeded 100 miles peak altitude. It will be flown four times at Churchill during the IGY. Fig. 8 illustrates a time-of-flight accelerometer, which measures drag acceleration by measuring the time it takes for a bobbin to traverse the distance from its central caged position to a concentric cavity. The accelerometer is mounted in a 7-in. rigid sphere,

(*Continued on page 280*)

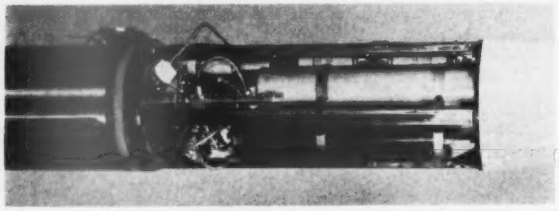

Fig. 7 Alphatron pressure gages mounted in University of Michigan Cajun

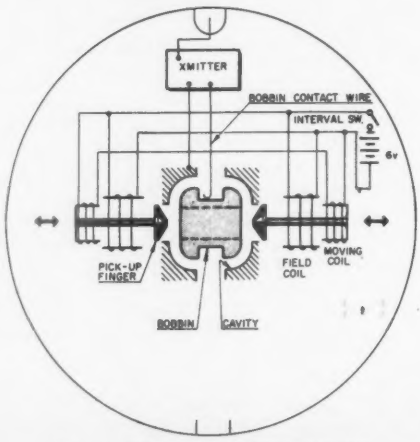

Fig. 8 Time-of-flight accelerometer

Future Sounding Rockets

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Economic considerations, which have been of great importance in the past, will continue to be the underlying philosophy in the design of future sounding rockets. Increased summit altitudes and reliability, ease of servicing, and mobility of launch, as well as low unit cost, are used as criteria to evolve a group of suitable sounding rockets. The Aerobee has potential capability of a 250-mile summit altitude with launching mobility and facilitated servicing. An advanced vehicle similar to the Aerobee employs four thrust chambers in a unique application to extend the summit altitude above 300 miles. A vehicle known as the Spaerobee simply adds a second stage to the Aerobee to give a summit altitude capability of 350 miles with a 40-lb payload. Extreme launching flexibility can be achieved by firing a sounding rocket from an airplane which has zoomed into a vertical attitude. The single-stage Aerosound propels a 40-lb payload to 45 miles, while a two-stage Aerosound reaches over 100 miles with the same payload. Using presently available solid propellant rockets, staged vehicles can be assembled yielding almost any desired performance. While takeoff gross weight may be relatively high, unit costs are strikingly low.

PERHAPS this discussion should have been entitled "Some Considerations of Future Sounding Rocket Systems," for this, in essence, is both the subject of the discussion and one of its keynotes: consideration of systems rather than the rockets alone.

It is the task of the rocket manufacturer to provide an integrated system for transporting a given payload from the launching site to a desired altitude with, perhaps, certain technical limitations placed on the manner in which the payload arrives at the altitude. In addition to the design of a vehicle suitable for the task, consideration also must be given to the support requirements. The combined effort results in what might be called "sounding-rocket-system complex."

In all divisions of the military, the economic aspects of the research, development, and production efforts are of great importance. Of these, it is the research effort which suffers most from relatively severe funding limitations. Because the use of sounding rockets is restricted, primarily, to the research agencies of the military, development of the experimentation techniques and of the vehicles themselves has been impeded, significantly, due to these funding limitations.

Alleviation of the economic restrictions on sounding rocket development can be accomplished, to some extent, by utilizing available components and techniques of more liberally funded weapons system programs. In the past this has been impractical because the vehicle performance required by the research scientists in the upper atmosphere field usually exceeded the performance obtainable from combat-type weapons systems. This situation today, however, is somewhat improved since there are numerous systems developed, or under development, which can satisfy the performance requirements. Although development costs can be reduced greatly by utilizing the technological advances incorporated in the weapons system programs, high unit costs and economics of logistics and handling of many of these systems prevent the complete elimination of the funding problem for future sounding rockets.

Despite the economic problems associated with the development of sounding rockets, significant improvements, although relatively gradual, have been effected both in vehicle performance and in handling techniques. Those improvements, which have been funded, were accepted with the full realization that in many respects an engineering guess was substituted for a more costly analytical and experimental evaluation. A good example of the progress which has been made in sounding rocket development in the past ten years is the Aerojet-General Corp. Aerobee. In 1946 the Aerobee burnout velocity of 4500 fps was outstandingly higher than almost any other vehicle; yet, today, a burnout velocity of 7200 fps for the Aerobee-Hi is approached by several vehicles, and even exceeded by some.

Within the presently conceived ground rules for the Aerobee-type vehicle an approximate upper limit in altitude capability can be derived. Consider a single-stage, boosted or unboosted rocket with a constant sustainer propellant flow rate which is fin stabilized and unguided. Because of aerodynamic stability requirements the burnout altitude should not exceed approximately 160,000 ft. As the summit altitude increases the speeds must increase during the burning period below 160,000 ft. The resultant increase in aerodynamic heating places upper limits on the burnout velocity and hence the summit altitude. Present indications are that limiting summit altitudes for the Aerobee-type vehicle are in the range of 250 miles. Developmental efforts could yield further gains but economic considerations are restrictive. As will be mentioned, deviations from the ground rules hold promise of further improved performance.

It is also in the logistics of the Aerobee system that further significant gains are to be obtained. The immobility of the launching sites and the presently practiced servicing procedures are satisfactory for a research vehicle in most cases. This does not eliminate the desirability of a mobile launching system and a more rapid servicing procedure. The substitution of a 33,000 or 36,000-lb thrust booster will permit launching from a 70-ft rail with slightly increased impact dispersion. A 70-ft launcher can be designed to fold into two 35-ft sections, allowing its mobile installation on a truck flatbed.

A pressurized propellant and helium feed system to load the Aerobee promises time-savings and hence cost-savings in vehicle servicing. The fuel and oxidizer would be quickly and reliably pumped by gas under pressure from the servicing tanks to the vehicle's tanks in much the same way that those same propellants subsequently would be pumped from the vehicle's tanks to the thrust chamber during flight. Servicing times could be reduced to minutes through this procedure. It is to be noted that air transportation of this complete sounding rocket system is feasible in military cargo airplanes.

With reference to the philosophies and restrictions men-

Presented at the ARS 11th Annual Meeting, New York, N. Y., Nov. 26–29, 1956.

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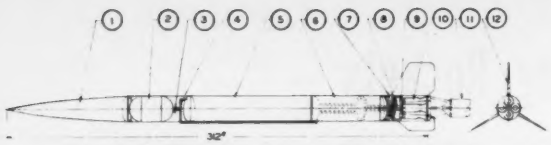


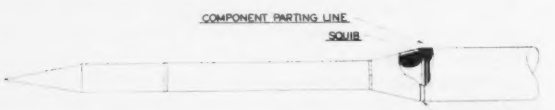
Fig. 1. High performance sounding rocket

1. Nose assembly and payload compartment
2. Pressure tank
3. Regulator valve
4. Check valve
5. Oxidizer tank
6. Fuel tank
7. Tailcone assembly
8. Booster line valve (1 required)
9. Propellant control valve (4 required)
10. Thrust chamber (4 required)
11. Solid booster
12. Fin assembly

tioned thus far an advanced sounding rocket system has evolved and is shown in Fig. 1. The criteria for performance of this vehicle is a summit altitude in excess of 300 miles with a 100-lb payload. Cost of developing and producing the vehicle would be minimized by using, to a large extent, components which are already in production. Pressure regulators, valves, and ceramic-lined thrust chambers from a propulsion system in production would be used. An inert-gas-pressurized propellant feed system similar to the Aerobee system would feed the thrust chamber. These chambers would be fired in pairs, four being installed in the vehicle. Two units would be fired initially and slowly accelerate the rocket through the dense lower atmosphere to avoid aerodynamic heating. At about 60,000 to 80,000-ft altitude the third and fourth units are fired, doubling the acceleration. Burnout altitude is thus lowered for the given propellant weight, effecting a retention of aerodynamic stability until burnout. It can be seen that this becomes a deviation from the ground rules for the Aerobee mentioned previously. Specifically, the criteria of constant propellant flow rate is eliminated in order to exceed 250 miles without encountering aerodynamic heating problems. Launching mobility and servicing facility are effected in the manner already described; a 2.0KS-36250 booster is employed as well as pressurized propellant servicing.

The vehicle would be 18 in. in diam and 312 in. long with a total weight of 2268 lb including a 100-lb payload. Each thrust chamber produces 2600 lb of thrust at sea level using inhibited red fuming nitric acid as the oxidizer and aniline base fuel. Other propellants also may be considered. The use of an 18-in.-diam body does not disqualify the use of the White Sands Proving Ground, Holloman Air Development Center, or Fort Churchill, Canada, launching towers, since their design permits them to be easily adapted to accept the larger vehicle.

Future requirements for experimentation at altitudes well above 300 miles cannot be discounted. A scheme for transporting a 20- to 60-lb payload to an altitude of approximately 400 miles, which utilizes existing components assembled with a minimum of development effort, consists, in essence, of a standard Aerobee as a first stage and a short-duration



Second stage and component separation device

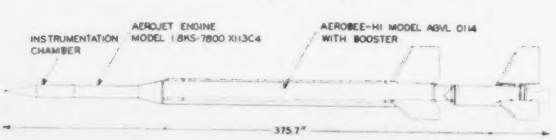


Fig. 2. Two-stage sounding rocket

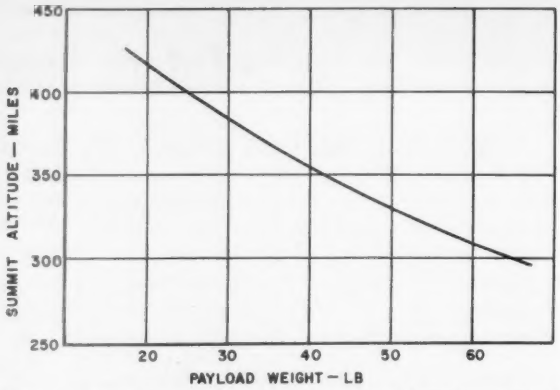


Fig. 3. Spaerobee sounding rocket, sea level launch—effect of payload variation on summit altitude

solid engine powered second stage. A sketch of the assembled configuration known as the Spaerobee is shown in Fig. 2; calculated performance, presented as summit altitude as a function of payload weight, is shown in Fig. 3.

The first stage consists of the Aerobee Model AGVL 0114 and its booster, modified to the extent of removing the nose section of the Aerobee. The second stage is formed by adding a nose cone, a cylindrical extension, and a stabilizing skirt to an Aerojet-General 1.8 KS 7800 solid engine. The payload, ranging from 20 to 60 lb, can be housed in the conical nose and cylindrical section. Relatively minor engine modifications, such as increasing the exhaust nozzle exit area and adapting an igniter suitable for vacuum operation, have been incorporated.

For this configuration, the second stage is attached to the first by a mechanism incorporating a V-band clamp. Separation is to be accomplished by breaking the clamp by means of a charge-driven piston which drives a T-bolt from place, thereby opening the V-band. The separation charge, as well as the second-stage igniter, is to be energized by the circuit for the Aerobee propellant shutoff valve. In this way separation and second-stage firing will be initiated simultaneously with Aerobee shutdown by a single electrical impulse.

The sounding rocket as visualized, consisting of a two-stage vehicle plus booster, will have the following advantageous features:

1 The vehicle consists, primarily, of a relatively simple combination of stock components. Development is restricted to design of a stage-separation device.

2 Use of the solid engine second stage maintains storage and handling complexity at a level existent for ordinary Aerobee sounding rockets.

3 Satisfactory compromise between aerodynamic heating and static stability is attained without a guidance system by incorporating a stabilizing-skirt and a short-duration high thrust engine for the second stage. The factors effecting this satisfactory compromise are: (a) Aerobee burnout occurs at altitudes high enough that second-stage aerodynamic heating should not be a serious problem. (b) The stabilizing-skirt retains its effectiveness at the high Mach numbers reached by the second stage (burnout velocity was calculated to be approximately 10,500 fps). (c) Because of the short duration of powered second-stage flight, burnout will occur at an altitude low enough that adequate aerodynamic restoring moments will be provided.

When extreme flexibility and mobility of launching site is a requirement, an airborne launching platform offers obvious advantages. A system known as Rockair has been considered for several years and holds promise of achieving the near ultimate in launching mobility. Basically, the system is a launching airplane which zooms into a vertical attitude and

fires a suitable sounding rocket upward.

The complete system analysis requires that primary consideration be given to pilot safety. Rocket engine reliability then becomes most important. Through this reasoning the field of applicable engines is reduced to a few units.

Adding the considerations of development costs, development time, unit costs, unit availability, engine size and performance and its ability to withstand rough handling and temperature cycling, the 1.8 KS 7800 solid propellant rocket mentioned in the previous section appears most satisfactory. It is a production unit of moderate cost designed for tactical usage which has exhibited, under peripheral test conditions, extremely high reliability. The unit is, at this time, "safe" for airborne operation. It is believed that the Douglas Aircraft Company has a Rockair system under development, which utilizes this solid rocket engine, and is planning its launching in the near future.

To illustrate a typical configuration of this type, and its performance, it seems in order at this time to present results of Aerojet's planning concerning a Rockair system. The vehicle, which has been designated the Aerosound (Fig. 4) was designed to incorporate the 1.8 KS 7800 engine and is essentially the same vehicle as was suggested for launching from the nose of the Aerobee. The engine supports a payload at its head end with a minimum of necessary aerodynamic fairings. A simple cone-cylinder fairing covers the payload and contours smoothly into the motor case. To provide the necessary static stability four tail fins have been attached instead of the conical skirt of the previous application. The fins join into a cylindrical fairing which covers the rocket nozzle.

Nominal performance is with a 40-lb payload launched at 0.8 Mach number at 35,000 ft altitude. Under these conditions a summit altitude of 45 miles would be reached, as shown in Fig. 5. The summit altitude increases to 54 miles with a 20-lb payload.

Mounting two 1.8KS-7800 engines in tandem and firing them sequentially under the foregoing conditions yields a substantial 110-mile summit altitude. Increases in complication and cost for the dual configuration are minor, considering that the summit altitude is more than doubled.

The often varied needs of the scientist result in a variety of vehicle requirements. The high altitude sounding rocket, for example, can be made up with solid propellant rocket units in two ways: First, a high performance system can be designed with optimum stage-weight ratios, based upon the payload and destination. This is the smallest, most efficient configuration, but is also the most costly in time and expenditure if a small number of units are to be produced. Second, standard production rockets can be assembled and flown with lower cost and a high order of reliability due to the long backlog of operational experience with these units. This second system, although less efficient and consequently much larger, is capable of carrying any reasonable payload to the limits of the earth's atmosphere.

Solid propellant rockets can be divided into two classes with separate applications to the high altitude ballistic problem. First are the long-burning-time boosters with relatively low impulse-weight ratios. These boosters can be used to elevate rockets of the second class, those of higher performance, shorter burning time, to altitudes which reduce drag and heat transfer effects to acceptable levels. The high performance units are available with a fairly broad range of total impulse values, and these can be assembled in multiple units when it is necessary to carry heavier payloads.

A sounding rocket system of standard solid propellant units can take advantage of the operational facility and logistic advantages which have for a long time been associated with this type of rocket power plant. In addition, the launching equipment can be held to a minimum if the ballistic requirements permit a free-rolling flight. A free-rolling missile effectively neutralizes the dispersion due to thrust misalignments, naturally present when firing several boosters simultaneously. Roll control and effective thrust misalignment correction can be otherwise obtained by jet vane control devices located in the booster jet streams. The use of such booster jet vanes permits operation with a zero-length launcher but adds complication and expense to the rocket system.

Fig. 4. Aerosound sounding rocket—vertical launch at 35,000 ft, altitude at Mach 0.8

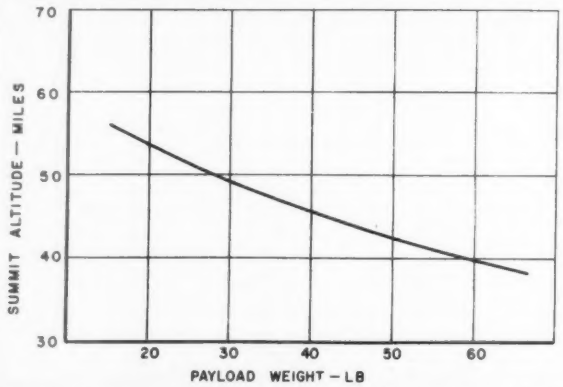


Fig. 5. Aerosound—effect of payload variation on summit altitude

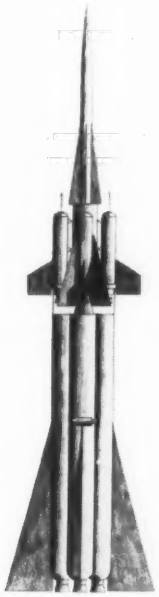


Fig. 6

An example of a high altitude solid propellant sounding rocket is illustrated by the configuration shown in Fig. 6. This system of rockets can send a free-coasting $6^1/_2$-in.-diam 250-lb payload up to 90 miles. The operational schedule is as follows:

1 Time zero—the boosters are fired, duration 40 sec, and result in a 900 fps burnout speed at 15,000 ft altitude (Table 1).

2 Time zero plus $^1/_2$ sec—the roll boosters are fired, applying a rolling moment near the center of gravity of the configuration which results in approximately 2 cps of roll rate.

3 Time zero plus 40 sec—the second-stage units are fired carrying the payload to Mach 2 and 22,000 ft (Table 2).

4 Time zero plus 45 sec—the third stage is fired with

Table 1 Booster ballistics

Payload (including fins and attachments)	250 lb
2KS-36,250 (second stage)	485
Fins (second stage)	40
	775
Four 5KS-4500 boosters (first stage)	908
Fins (first stage)	123
	1806
Four 5ONS-4500 boosters	9520
Booster fins and roll boosters	1100
Total initial weight, boost stage W_0	12,426
Burnout weight, boost stage W_{40}	8,434

Launch at sea level with zero length launcher

Diam = 38.6 in.; Area = 8.126 ft²

$$M_0 = \frac{12426}{32.16} = 56.157 \text{ slug}; \quad M_{45} = \frac{8434}{32.16} = 42.10 \text{ slug}$$

Time t sec	Mass M slugs	Mass ratio M/M_0	Vacuum speed ($s \ln M/M_0 = gt$) fps	Altitude $h \times 10^{-3}$ ft	Drag Coef. C_D	Velocity V fps
0	386.40	1.0000	0	0	0.3	0
4	373.98	0.9678	57.48	0.115	0.3	57.43
8	361.56	0.9383	105.30	0.446	0.3	105.05
12	349.14	0.9036	191.25	1.006	0.3	190.31
16	336.72	0.8714	268.9	1.960	0.3	266.2
20	324.30	0.8393	354.0	3.152	0.3	348.3
24	311.88	0.8071	448.0	4.770	0.3	437.1
28	299.46	0.7750	550.4	6.684	0.3	531.9
32	287.04	0.7428	663.1	9.077	0.3	633.8
36	274.62	0.7107	786.0	11.82	0.3	742.1
40	262.20	0.6786	920.4	15.098	0.35	856.6

Table 2 First stage ballistics

Payload (including fins and attachments)	250 lb
2KS-36,250 (second stage)	485
Fins (second stage)	40
	775
Four 5KS-4500 boosters (first stage)	908
Fins (first stage)	123
Total initial weight W_{40}	1806
Burnout weight W_{45}	1354

$$M_{40} = \frac{W_{40}}{g} = 386.40 \text{ slug}; \quad M_{45} = \frac{W_0}{g} = 262.20 \text{ slug}$$

Time t sec	Mass M slugs	Mass ratio M/M_{40}	Vacuum speed ($V_{40} + s \ln M/M_{40} - gt$) fps	Altitude $h \times 10^{-3}$ ft	Drag Coef. C_D	Velocity V fps
40	56.157	1.0000	856.6	15.098	0.3500	856.6
40.5	54.751	0.9750	1010.6	15.561	0.5000	994.9
41.0	53.345	0.9499	1170.0	16.093	0.8200	1124
41.5	51.940	0.9249	1333.3	16.687	0.8035	1234
42.0	50.534	0.8999	1501.4	17.336	0.7865	1349
42.5	49.128	0.8748	1675.5	18.044	0.7717	1452
43.0	47.723	0.8498	1854.3	18.801	0.7566	1560
43.5	46.317	0.8248	2038.5	19.613	0.7438	1654
44.0	44.911	0.7997	2230.1	20.461	0.7307	1758
44.5	43.506	0.7747	2427.8	21.274	0.7201	1849
45.0	42.100	0.7497	2632.1	22.293	0.7091	1951

payload separation at burnout altitude of 30,000 ft and Mach 6 (Table 3).

5 The payload coasts to 90 miles at zero plus 3.6 min.

An alternate payload configuration is shown in Table 4 where the 250 lb are used for another rocket stage that carries 50 lb to a summit of 490 miles. This high performance rocket is an Aerojet-General loaded ASP, produced by the Cooper Development Corp.

We have seen from this discussion of criteria and specific vehicle systems that increased summit altitudes are but one of the several improvements that will constitute the future sounding rockets. Economic considerations, as in the past, will continue to underlie all other criteria. Mobility and servicing ease are receiving, and will continue to receive, increased attention. Low cost, highly reliable, easily serviced, mobile launched vehicles with operating ranges from 40 to 400 miles and payloads from 20 to 250 lb are considered to be the requirements for a desirable family of upper atmospheric sounding rockets.

Table 3 Second stage ballistics

Payload (including fins and attachments)	250 lb
2KS-36,250 (second stage)	485
Fins (second stage)	40
Total initial weight W_{45}	775
Burnout weight W_{47}	447

$$M_{45} = \frac{775}{32.6} = 24.098 \text{ slug}; \quad M_{45} = \frac{447}{32.6} = 13.899 \text{ slugs}$$

Time t sec	Mass M Slugs	Mass ratio M/M_{45}	Vacuum speed $(V_{45} + s \ln M/M_{45} - gt)$ fps	Altitude $h \times 10^{-3}$ ft	Drag Coef. C_D	Velocity V fps
45.0	24.098	1.000	1951.0	22.29	0.5276	1951
45.2	23.078	0.9577	2280.8	22.71	0.4979	2267
45.4	22.058	0.9153	2626.9	23.20	0.4688	2596
45.6	21.038	0.8730	2988.6	23.75	0 4403	2935
45.8	20.018	0.8307	3369.0	24.37	0.4124	3289
46.0	18.998	0.7884	3768.8	25.07	0.3852	3656
46.2	17.979	0.7461	4192.0	25.84	0.3584	4041
46.4	16.959	0.7038	4640.1	26.69	0.3324	4444
46.6	15.939	0.6614	5117.0	27.62	0.3068	4870
46.8	14.929	0.6195	5619.6	28.64	0.2787	5315
47.0	13.899	0.5768	6168.9	29.76	0.2544	5799

Table 4

Payload
Diam = $6^1/_2$ in.
Weight = 250 lb

Trajectory
Supersonic $C_D = {}^3/_4 \times e^{-0.185 \text{ Mach}}$

Altitude $h \times 10^{-3}$ ft	Time t sec	Velocity V fps	Deceleration $D/M + g$ fps	Mach No.	Drag Coef. C_D
30	47.0	5800	145.04	5.8327	0 2549
70	54.7	5187	47.79	5.3450	0.2790
110	62.9	4874	34.32	4.9008	0.3029
150	71.6	4594	32.52	3.9190	0.3632
190	80.9	4303	32.25	3.5015	0.3924
230	90.9	3992	32.19	3.5814	0.3866

h-peak	t-peak
477,800 ft	214.9 sec
90.5 miles	3.6 min

Alternate payload of 50 lb with third-stage rocket (250 lb total)

Payload	50
4KS-8000 (including fins)	200
Total initial weight	250
Burnout weight	100

Altitude $h \times 10^{-3}$ ft	Time t sec	Mass	Velocity V fps	Deceleration $D/M + g$ fps	Mach No.	Drag Coef. C_D
30	47	7.774	5800	145	5.83	0.2549
60	51	3.109	12900	145	13.28	0.0910
180	64	3.109	12000	32.9	9.76	0.1232

h-peak	t-peak
460 miles	20.5 min

The ASP, a Single-Stage Solid Propellant Sounding Rocket

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The ASP is a single-stage solid propellant sounding rocket 6 1/2 in. in diam and 12 ft long. It is capable of transporting a 550 cu in. payload weighing 25 lb to an altitude of 200,000 ft. When lauched from sea level, burnout velocities of the order of 5700 fps have been experienced. At White Sands Proving Ground, as a staged vehicle employing a Nike booster as the first stage, the ASP is capable of reaching 850,000 ft. In addition to its capabilities as a sounding vehicle, the ASP can also be utilized as an aerodynamic test vehicle either as a single-stage, a multiple-stage, or a clustered vehicle. Fifty-one flight tests have been made with a perfect reliability record of 100 per cent successful firings.

THE ASP, a single-stage solid propellant rocket, was designed and built by the Cooper Development Corp., as prime contractor under NObs 72000 for the Bureau of Ships. Since our program was part of Operation Redwing, no discussion will be offered relative to the telemetering system, instrumentation, or ground receiving equipment. The Naval Radiological Defense Laboratory was the cognizant technical agency for the Government.

The Cooper Development Corp. as prime contractor was responsible for the over-all program, including the design of the basic vehicle, the external ballistics, the instrumentation, the field test program, the acquisition of data, and the final data reduction. The development of the propellant was subcontracted to the Grand Central Rocket Co., Redlands, Calif. Since the motor also served as part of the rocket airframe, the Cooper Development Corp. included as part of its responsibility the design, the development, and the fabrication of the motor case; Grand Central had the responsibility for the internal ballistics, the propellant loading, and the static firing.

Description of Vehicle

The configuration of the basic ASP rocket consists of three major subassemblies: the ogive, or telemetering head; the rocket airframe, or rocket motor case; and the fin and after skirt assembly. The ASP's basic dimensions are shown in Fig. 1. The ogive is threaded to the forward end of the rocket airframe and the fins are roll pinned to the after skirt which in turn is roll pinned to the after end of the rocket airframe. To induce roll during burning, the after closure of the fins also serves as a spinneron.

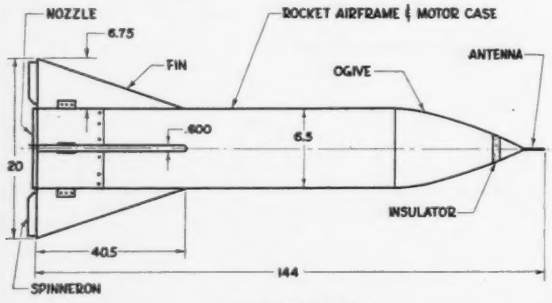

Fig. 1 The ASP

Presented at the ARS 11th Annual Meeting, New York, N. Y., Nov. 26-29, 1956.

[1] Chief Engineer.

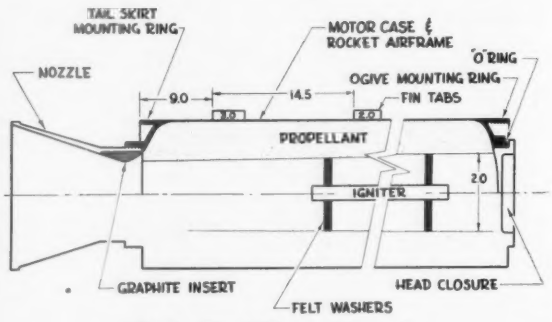

Fig. 2 The ASP propulsion unit

The ASP propulsion unit as shown in Fig. 2 was fabricated from two deep-drawn tubular sections, butt welded together. Two rings were welded to each half of the case prior to welding them together. The forward rings served as attachment points for the ogive and motor head closure. The after rings provided the attachment for the tail skirt and nozzle. In addition, sixteen tabs were welded to the motor case to provide lateral stabilization of the fins. The motor was made pressure tight at the head end by means of an O-ring seal, whereas the nozzle utilized a conical seat. The case and closure were fabricated from 4130 and heat treated to 180,000 to 200,000 psi ultimate tensile strength. The nozzle was made from a 1020 tubular swaging with a graphite insert at the throat section.

The propellant is GCRC 201-C, an ammonium perchlorate-polysulfide rubber-type propellant similar to JPL 131. The motor burns for approximately 6.0 sec, producing an average thrust of 5850 lb at sea level at 80 F. The total impulse under the same conditions is 31,000 lb seconds. The specific impulse is approximately 211 and the impulse to motor weight ratio is approximately 162.

The fins consist of a welded tubular chrome moly frame covered with a mild steel skin which is riveted to the frame. The fins were roll pinned to the after skirt as shown in Fig. 3. The frame consists of 1/2 in. square steel tubing with a longeron running full length at the fin root with four short spars to carry the bending loads. The frame is slotted at two points along the base to receive the tabs on the airframe for lateral stabilization to eliminate flutter. Each fin is fitted to two tabs on the skirt assembly. The primary bending and torsion loads are transferred to a ring in the skirt assembly by means

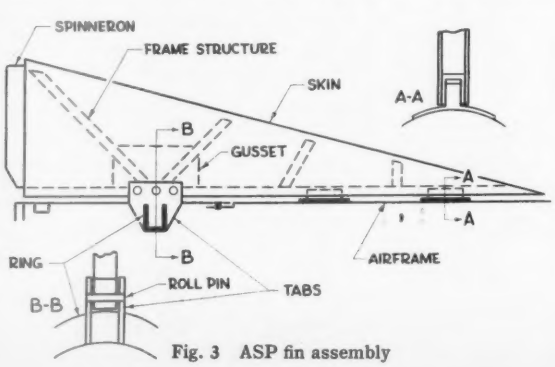

Fig. 3 ASP fin assembly

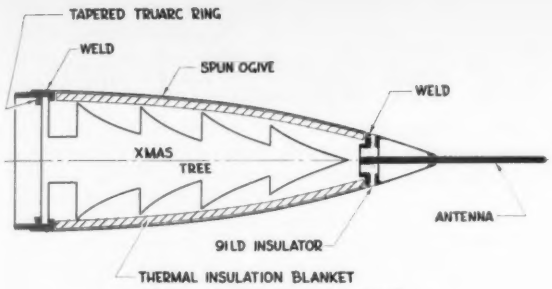

Fig. 4 Instrumentation head

of these skirt tabs. The two forward tabs on the motor are designed to take only shear, since their primary purpose is to stabilize the fin.

The telemetering head consists of five components: the antenna, the insulator, the ogive, the thermal barrier, and the telemetering and instrumentation mounting structure as shown in Fig. 4. The antenna is a quarter-wave spike antenna which was threaded to a 91LD Fiberglas insulator. A conical fairing of mild steel was silver brazed to the antenna spike which was of heat treated 4130. The 91LD insulator was likewise threaded to the ogive. The ogive proper consisted of a mild steel spinning to which a diaphragm-type fitting was welded at the forward end and a heavy ring welded aft. The after ring was externally threaded to make the joint and internally machined to hold the telemetering mounting structure. The telemetering mounting structure is held in place with a tapered Truarc ring. The ogive spinning was made by rolling flat sheet into a cone, seam welding the joint, and spinning the cone after dressing down the weld. To protect the instrumentation from the heat resulting from aerodynamic heating, a thermal insulation blanket was cemented to the ogive wall. The net volume of this design available for instrumentation is approximately 550 cu in.

The ASP is launched by means of a monorail launcher consisting of a channel strongback with a flat bar stock rail. The missile is supported by two skids which fit over the rail as shown in Fig. 5. The missile is attached to the after shoe by means of a brass shear bolt. The missile is attached to the forward shoe by a hook, such that a combination of gravitational and aerodynamic forces remove the shoe from the body when clear of the launcher. Zero tipoff is achieved by stopping the after shoe and, as the missile slips off the after shoe, the forward shoe drops clear of the launcher. The forward shoe is relieved to clear the stopper block and facilitate loading.

Performance

The ASP has been flight tested at the Naval Air Missile Test Center, Pt. Mugu, Calif., and the Naval Ordnance Missile Test Facility, White Sands Proving Ground, New Mex. When fired at initial launch angle of 30 deg, burnout velocities of the order of 5350 fps have been obtained with sea level firings at Pt. Mugu and of the order of 5700 fps for a launching elevation of 4000 ft at White Sands Proving Ground. Based on results obtained from flight test data, it has been calculated that the summit altitude for a vertical firing from sea level would be in excess of 200,000 ft. These data are for the basic ASP configuration with a payload of 25 lb. The launching weight of these vehicles was 245 lb and the burnout weight 95 lb.

Four rounds were fired at Pt. Mugu; three at a quadrant elevation of 30 deg and one at a quadrant elevation of 75 deg. The purpose of these tests was to prove out the system under most critical conditions from the standpoint of telemetering reception and environment resulting from aerodynamic heating. Inclement weather on the coast of California necessitated continuance of the flight test program at White Sands. Five rounds were successfully fired at White Sands. All

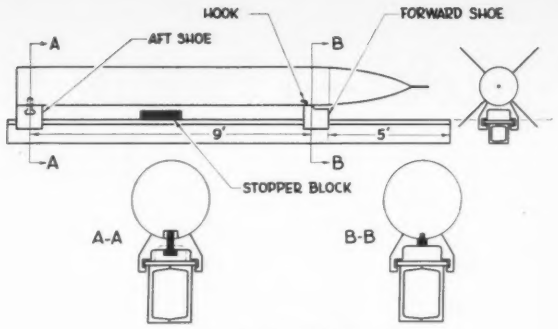

Fig. 5 Launching

Fig. 6 ASP ready for launching

of the rounds were fired at a quadrant elevation of 30 deg for ballistic data. One round fired at White Sands was recovered.

Forty-one missiles were fired at the Pacific Proving Ground and to date not a single flight failure has been experienced. In addition, thirty rounds were static fired at temperatures varying between 30 F and 130 F without experiencing a single failure. Therefore, we have had 80 successful firings with a 100 per cent reliability record.

Applications

The ASP is adaptable to a variety of purposes. As a single-stage vehicle, it is capable of summit altitudes of 200,000 ft with a 25-lb payload and 170,000 ft with a 50-lb payload when fired from sea level. When fired from a 4000-ft elevation, the comparable summit altitudes are 240,000 ft and 200,000 ft, respectively. When used as a Rockoon, i.e., a balloon-launched rocket, the ASP will reach 640,000 ft with 25 lb and 500,000 ft with 50 lb.

The ASP can also be used as an aerodynamic test vehicle, as a single-stage vehicle, as a multiple-stage vehicle, or even a clustered vehicle.

As a two-stage unit, employing a Nike booster similar to to the Deacon-Nike or Cajun-Nike, the ASP has an altitude capability of 850,000 ft with a 25-lb payload.

Tactically, the ASP can be used as a high performance air-to-air or ground-to-air missile with the addition of guidance. Perhaps, some day, the ASP may even be the last stage of a satellite vehicle.

Rockair—A Promising New Tool for Specialized High Altitude Research

MALCOLM D. ROSS[1] and JOHN E. MASTERSON[2]

Office of Naval Research

A standard 2.75-in. FFAR (folding fin aircraft rocket) rocket nose cone was instrumented to detect cosmic ray radiation and to telemeter this information as a qualitative measurement of flight time and altitude. The information was telemetered by a standard radiosonde transmitter. The 2.75-in. FFAR launched from a Navy F2H2 Banshee fighter reached an altitude of approximately 180,000 ft. The cost of this service production rocket prior to modification is in the neighborhood of $50.

ROCKAIR as a research tool is too new for a comprehensive evaluation of its unique capabilities, limitations, and possible uses at this time. On the basis of feasibility tests conducted, however, it appears to have promise for conducting specialized investigations which are intriguing. Because of its inherent limitations it will probably not be used as extensively as other high altitude research tools. Nevertheless, its potential needs to be explored further.

The Rockoon system (1)[3] of combining the Skyhook plastic balloon with the inexpensive Deacon rocket to provide a low cost vehicle to probe the lower ionosphere inspired S. Fred Singer, of the Office of Naval Research, in 1953 to propose an extension of the same technique with an aircraft (Fig. 1) replacing the balloon (2). Subsequently, while at the University of Maryland, his suggestion was revised to a scheme which required a minimum of development. It consisted of a modest experimental program using production 2.75-in. FFAR (folding fin aircraft rocket) rockets, standard 2.75-in. aircraft rocket launchers, and the assignment of an available Navy aircraft for conducting the tests. Since the cost of 2.75-in. rockets was less than $50, the suggestion was quite attractive. The only development required was a nose cone modification to include a simple Geiger Müller tube for detecting cosmic radiation and a miniaturized radio transmitter for telemetering the information to a ground station.

When the 2.75-in. FFAR was selected for the feasibility tests of Rockair, severe limitations were imposed on the instrumentation because of the weight and space restrictions in

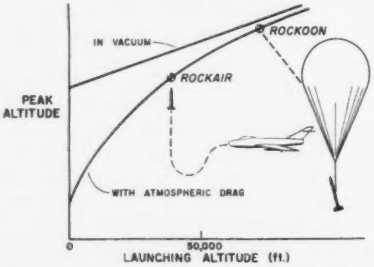

Fig. 1 Comparison of Rockair and Rockoon altitude capabilities with equivalent rocket

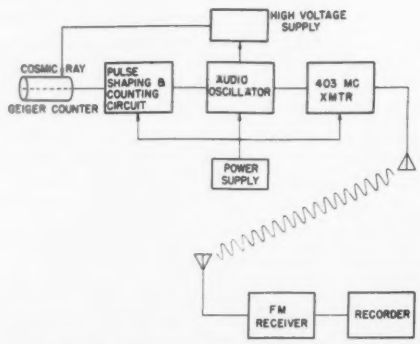

Fig. 2 Rockair instrumentation for 2.75-in. rocket

the nose cone. It was desired that the external characteristics, the total weight, and the center of gravity of the standard service rocket be retained with a minimum of deviation. Thus, the sensing, transmitter, and power elements had to be light and small.

The actual modification to the rocket head included machining $^{7}/_{16}$ in. from the inner wall of the nose cone, cutting the nose cone transversely and adding a threaded polystyrene $^{5}/_{8}$-in. insulator to provide a dipole antenna, and replacing the nose tip fuse with an identical configuration of nylon. The largest diameter for accommodation of the instrumentation was increased to 2.630 in. The total interior space available was approximately 32 cu in. Physical characteristics of the standard 2.75-in. FFAR are: approximate length, 48 in.; diameter, 2.75 in.; approximate weight of head, 6.5 lb; approximate total weight before firing, 18.1 lb (3).

In order to miniaturize the instrumentation and power package an investigation was made of various equipment. A Geiger Müller tube (Victoreen Type 1B86), for obtaining cosmic ray data, and a modified Navy radiosonde transmitter operating on 403 megacycles were the basic components of the instrumentation. In conjunction with an antenna, receiver, and a tape recorder for playback and subsequent detailed data evaluation, it was concluded that the essential information would be available for demonstrating the feasibility of Rockair with a fair quantitative assessment of the peak altitude.

The principal considerations for the power supply were the available space, lifetime of the power pack, and ease of handling or activating in the field. An Eagle-Picher wet cell #723 was selected for the "A" supply. It provided a nominal voltage of 8 v in a volume of 1.64 cu in. with a lifetime of 30 min. For the "B" supply Eveready dry cells #413 were chosen. They supplied 120 v, were small (5.6 cu in.), and had a life of more than 1 hr.

The circuitry was designed (Fig. 2) and was integrated into the nose cone by laboratory personnel of the Physics Department of the University of Maryland. The instrumented rocket nose cone appeared practically no different from the standard service 2.75-in. FFAR rocket. The most recognizable change was the $^{5}/_{8}$-in. elongation of the nose cone.

Presented at the ARS 11th Annual Meeting, New York, N. Y., Nov. 26–29, 1956.

[1] Meteorologist, Air Branch, ONR; formerly, Lt. Commander, USNR, Rockair Coordinator for ONR.

[2] Commander, USNR, Geophysics Branch, ONR.

[3] Numbers in parentheses indicate References at end of paper.

The next phase of the program was testing of the instrumented nose cone. Data were needed regarding the antenna pattern, the relation between field strength and distance; the nose cone needed to be tested for acceleration, vibration, low pressures, and low temperatures.

Initial tests were conducted to map out the antenna pattern by suspending the test nose cone from an Army helicopter and making measurements on the ground while the helicopter hovered at various points near the ground station. In order to obtain field intensity measurements the same test nose cone was suspended from an Army L-19. Army aircraft were provided for these tests by the Army Transportation Corps at Fort Belvoir, Va.

After the transmitter characteristics of the rocket instrumentation were determined, and a "breadboard model" built, the Naval Ordnance Laboratory at White Oak, Md., made acceleration and vibration tests. Low pressure and cold temperature tests were next made in a vacuum chamber at the University of Maryland. The model was improved to correct minor weaknesses noted and the first experimental prototype of the instrumented 2.75-in. FFAR was approved (Fig. 3). Six units were ordered for the aircraft firing tests.

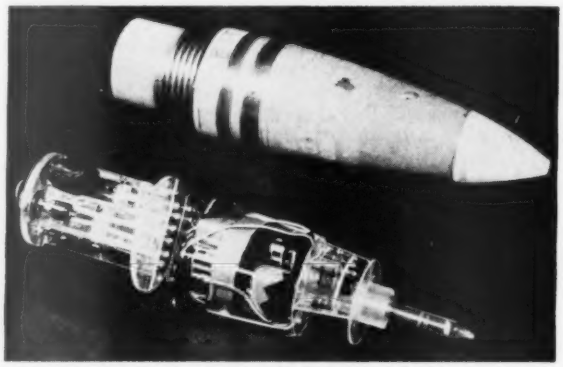

Fig. 3 Experimental prototype of the instrumented 2.75-in. FFAR

The Bureau of Aeronautics subsequently established a project with Armament Test Division of the Naval Air Test Center, Patuxent River, Md., to provide aircraft, determine the optimum maneuver for the particular aircraft assigned, and fire the rockets. By this time the program had attracted additional interest in connection with a fleet requirement for a rapid means of determining winds above 100,000 ft in the Pacific Proving Grounds. To meet the requirement it was considered likely that "window" or "chaff" ejected from a Rockair at its peak altitude might provide a suitable means for a rapid measurement of the high altitude winds. The Naval Research Laboratory was requested to study the practicability of using window for this means (4). Based on preliminary NRL data it was recognized that the 2.75-in. was too small to carry a tracking beacon and sufficient amounts of chaff for this use of Rockair. It was therefore decided to include a limited number of larger 5-in. HVAR (high velocity aircraft rocket) rockets in the test phase. It was too late in the program to instrument the 5-in. rockets, but it was decided to fire some of them in the Rockair maneuver.

The test program carried out by the Armament Test Division was broken down into three phases. The first phase was simply a series of seven practice flights to determine the optimum maneuver for an assigned F2H2 aircraft. The F2H2 built by McDonnell is called the Banshee. Standard 2.75-in. FFAR rockets were then fired singly in the Rockair maneuver from the standard Navy Aero 1A tube rocket launcher. Next a series of 2.75-in. rocket clusters were fired from the standard Aero 6A launcher and, finally, some 5-in. HVAR's were fired singly.

It should be mentioned that the Aero 6A is a standard pack of seven 2.75-in. rockets which are normally fired simultaneously in a cluster. Since they can be fired individually, the utility of Rockair as a research tool is extended for making various measurements within the time and area of one aircraft flight.

The maneuver determined as optimum can be described simply as a loop begun in level flight at 25,000-ft pressure altitude with an indicated airspeed of 320 to 330 knots. The vertical climb attitude was reached at 30,000 ft with an indicated airspeed between 150 and 200 knots. The aircraft pulled out of the loop at 34,000 ft with the airspeed reduced to between 60 and 80 knots.

Five instrumented 2.75-in. FFAR rockets were then launched off the NAOTS Chincoteague range, August 16, and November 4, 1955. Table 1 summarizes the essentials of each launch as recorded on the F2H2 instrument panel and reported by the Naval Air Test Center (5).

Table 1 Aircraft launch information

	Altitude of firing, ft MSL	True aircraft speed, knots	Angle of aircraft from horizontal, deg
1.	28,400	237	89
2.	28,800	195	88
3.	28,000	241	86
4.	30,440	193	87
5.	29,640	210	85

The average firing altitude was about 29,060 ft with an aircraft speed of 215 knots true. The angle of aircraft attitude was 87 deg.

The table indicates a reasonable capability of the pilot and aircraft for repeating the optimum maneuver. Success was achieved on only one firing, the second. On the first firing there was a malfunction in the rocket and it did not fire. The signal of the third rocket stopped at the time it was launched. Radio interference at the ground station prevented signal reception from the fourth and fifth rockets fired.

The completely successful test, however, was quite remarkable in its performance. Trajectory data were computed (6) and, based on a time-altitude plot, show a reasonably accurate peak altitude of 180,000 ft with a total flight time of 3 min 36 sec (Table 2). For measurements above 100,000 ft the trajectory shows that data might be collected for a period of 120 to 140 sec (Fig. 4).

Table 2 Summary of results[1]

	Flight in air		Flight in vacuum, no drag[2]
	Standard C_D	High C_D	
End of burning			
V_B (fps)	4,063	4,022	3,965
h_B (ft)	33,307	33,283	33,380
Peak altitude h (ft)	181,085	158,900	280,000
Time to peak t (sec)	96.1	87.6	123.0
Free fall t_{ff} (sec)	120.3	125.2	130.8
Total time t_T (sec)	216.4	212.8	253.8
Flight time t (min)	3 min 36 sec	3 min 33 sec	4 min 14 sec

[1] University of Maryland information (6).

[2] No initial velocity was assumed in *flight in vacuum* figures. The *flight in air* was computed considering aircraft velocities at time of rocket launch.

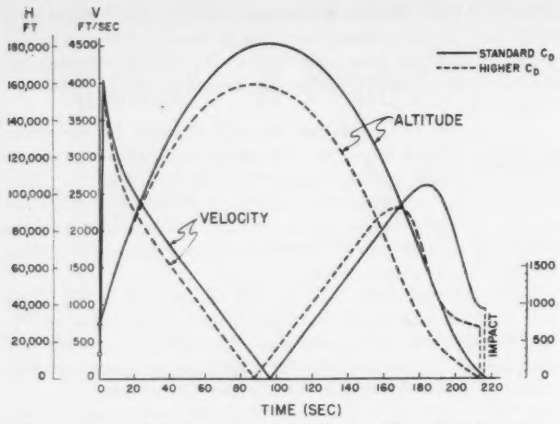

Fig. 4 Time-altitude-velocity curves of 2.75-in. Rockair test

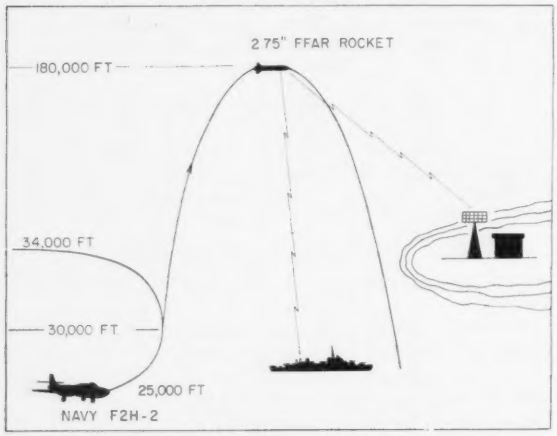

Fig. 5 Typical aircraft maneuver with indication of Rockair data monitoring by ship or shore station

Results of the program carried out were concluded as satisfactory and the feasibility of Rockair demonstrated at a minimum cost.

Although Rockair appears to have a limited potential it is also unique in some of its capabilities for specific research investigations. For example, it is feasible to carry fourteen instrumented 2.75-in. FFAR rockets on a plane launched from an aircraft carrier to an area otherwise inaccessible for shipboard or ground rocket launchings (Fig. 5). The telemetering would be of such nature that data would be received and recorded by the launching aircraft. For research purposes this would be stored until the plane returned to its base or ship. Among experiments that might be feasible using the 2.75-in. FFAR are, of course, cosmic ray experiments similar to those used in these feasibility tests. Ozone measurements, solar ultraviolet radiation, and, possibly, atmosphere composition experiments might be conducted with a rocket of this size. Numerous other experiments are primarily a matter of instrumentation, miniaturization, and ingenuity. The 5-in. HVAR, although we have no altitude data on this rocket, would lend itself to considerably more instrumentation. It is conceivable that the Rockair technique might be used to obtain synoptic measurements of meteorological parameters, such as pressure, temperature, and, if radar tracking were available from ships or land bases, wind speeds and directions.

It should be emphasized that the system developed and tested is one of the simplest conceivable forms of an entire "family" of Rockairs. Various types of rockets and aircraft with different capabilities can be selected for other systems where greater payloads and/or higher altitudes are desired. Development of a Rockair system with greater capability is being supported by the Bureau of Aeronautics within the Navy for meteorological observations. Coordination with the Air Force program is effected within the Department of Defense.

Acknowledgments

There were many personnel directly involved in the Rockair tests in addition to personnel of the Physics Department at the University of Maryland. It is almost impossible to mention names of all the individuals. The following, however, is a list of personnel who were especially helpful:

S. Fred Singer, University of Maryland
Jules Sreb, University of Maryland
Bruce Edwards, University of Maryland
Stanley Pickart, University of Maryland
Capt. W. C. Fortune, USN, ONR
Capt. Wallace G. Reid, USA, Army ATC Liaison Officer with ONR
Lt. Comdr. Richard G. Gleeson, NAS Chincoteague
Comdr. James Ellis, USN, NAOTS Chincoteague
Comdr. James Sands, USN, NATC, Patuxent River
E. A. Corwin, BuAer
C. C. Ballard, BuOrd
H. Demboski, Bu Aer
J. W. Smith, ONR
W. J. Thaler, ONR
J. W. Siry, NRL
Lt. Comdr. R. Z. Moore, USNR, ONR
Lt. John Chalbeck, USN, NATC Patuxent River
Comdr. V. M. Mayabb, USN, NAS Chincoteague
P. F. Spagnuolo, BuAer
E. H. Heinemann, Douglas Aircraft Co.

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The Air Force Rockaire Program

ROBERT M. SLAVIN[1]

Air Force Cambridge Research Center, Bedford, Mass.

To carry small payloads to altitudes of interest to the upper atmosphere research scientist, the capability of the aircraft launched rocket has been investigated. In a program already under way, the Air Force will utilize an 8-in. rocket to carry 40 lb to about 40 miles while retaining the mobility allowed by a completely airborne operation.

THE statement has been made many times that the upper atmosphere over New Mexico has been more thoroughly explored than that of any other region of the world. It was in an attempt to expand the area of exploration that the Rockaire program was instituted. The major objectives of the program have been that of carrying significant experiments to altitudes of interest to the scientist with a system capable of being used at a wide variety of latitudes and longitudes.

To clarify this statement let me say that we feel the phrase "significant experiments" implies a payload of between 30–40 lb and that in the matter of "altitudes of interest" significant contributions can be made by flights to altitudes of 40 miles and up.

The history of upper atmosphere research using rockets as vehicles has, in the past ten years, shown a trend toward simplification. The early multiple-experiment payloads of the V-2 had an "all your eggs in one basket" flavor which is a far cry from the one-experiment flights of the Cajun and Rockoon.

Most rockets, however, which could take advantage of this simplification to carry small payloads to altitudes of interest are sadly deficient when ground launched. The Deacon, for example, when ground launched will reach only to balloon altitudes. The reason for this is, of course, the extravagant consumption of available energy in getting through the lower and denser atmosphere.

Another drawback to ground launching is its lack of mobility. Fixed installations are generally necessary and even when these are relatively simple and inexpensive, range safety considerations severely limit the number and location of these installations. To get around these limitations on altitude and mobility, the launching of a rocket from a high altitude mobile platform is of course an obvious solution. One such mobile platform will be a balloon, and this technique has been thoroughly explored by the Rockoon flights of the past several years. A second approach to the problem of getting through the denser atmosphere and retaining mobility will be the launching of the rocket from an aircraft.

An early study of this technique was made in 1947 by Cook Research Laboratories at the request of Marcus O'Day of the Air Force. The conclusion of this study was that aircraft of that day did not have the performance capability to launch rockets at significant altitudes. At this time the project was also handicapped by the fact that no rockets suitable for research had been approved for launch from manned aircraft.

With the coming of age of jet aircraft and the conclusion of tests resulting in approval of a rocket of suitable size for manned aircraft launching, action was initiated to develop a system which we have named "Rockaire." The Douglas Aircraft Co. has been the major contractor in this development.

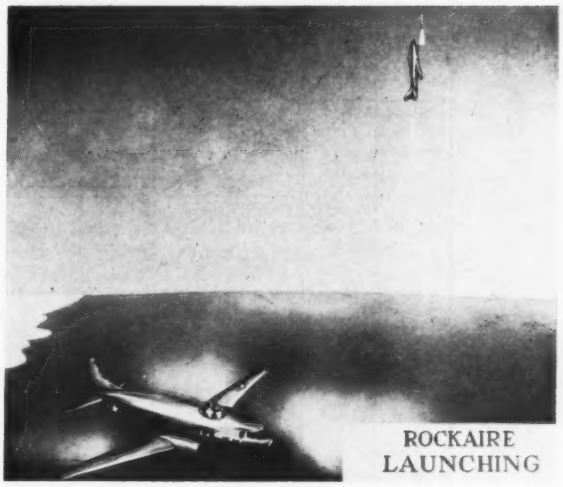

Fig. 1 Rockaire launching

In the first phase of this work, launchings are being made this month (November 1956) at Holloman Air Development Center to prove out the theoretical calculations which have been made on the system. As shown in Fig. 1, the rocket, using a standard production Jato for a motor, but with special airframe components attached, is carried under the wing of an F86D fighter aircraft. At 35,000 ft, the F-86 climbs to a vertical attitude and launches the rocket, using equipment similar to that used in the low altitude bombing system to attain the proper attitude. The fighter then continues up and over.

The configuration and performance of the rocket are shown in Fig. 2. Fig. 3 indicates the dependence of zenith altitude on payload and launch Mach number for a launch altitude of 35,000 ft. It will be noted that in the region of 40 lb, the slope of any one of these curves is approximately 2000 ft of zenith altitude per pound of payload. Fig. 4 shows the dependence of zenith altitude on launch altitude for several payloads. Again note that for 40-lb payload, for example, 1000-ft increased launch altitude buys about 7000 ft in zenith altitude.

The second phase of the program will be launching of

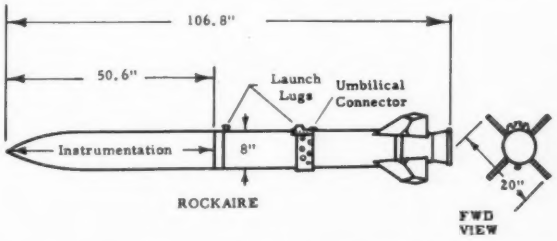

Fig. 2 Rockaire performance data (DM-16 Motor)—thrust, 7800 lb; burning time, 2.15 sec (60 F); total thrust, 15,000 lb-sec; propellant weight, 70.3 lb; specific impulse, 210 sec; launch weight (including 40-lb payload), 181.4 lb

Presented at the ARS 11th Annual Meeting, New York, N. Y., Nov. 26–29, 1956.

[1] Geophysics Research Directorate.

rockets instrumented for upper atmosphere research, but using ground tracking and telemetering. This phase will allow a certain amount of mobility to the program.

It is planned to obtain complete mobility in the third phase of the program in which an instrumented "mother ship," a C131B Convair carrying telemeter and tracking devices, will accompany the fighter to the launch point and collect data during the rocket flight. Fig. 5 indicates the data links which will be required for complete operation.

Generally, we feel our program is moving well. The system to be used allows for growth after the launchings which I have described have been accomplished. It is our intent to carry this program to the point where similar payloads can be carried by this technique to altitudes in the vicinity of 100 miles.

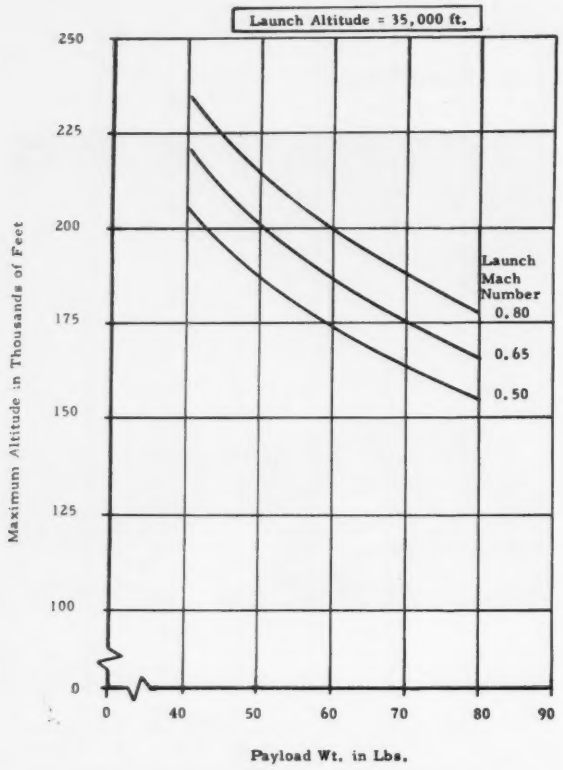

Fig. 3 Maximum altitude vs. payload weight

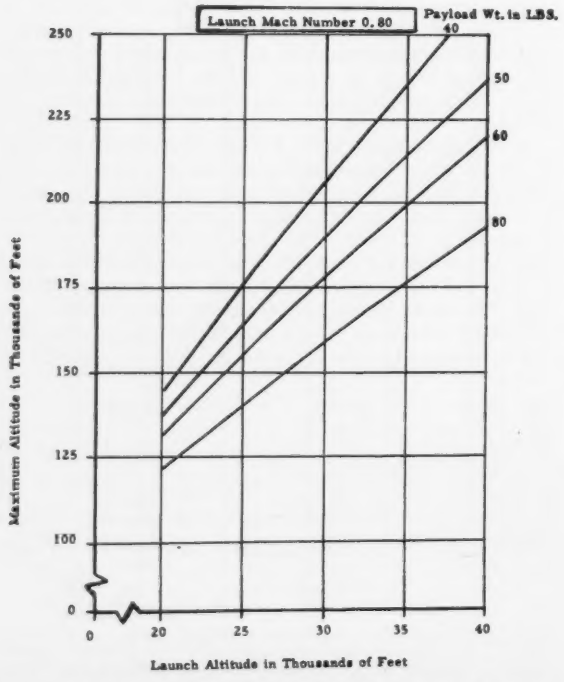

Fig. 4 Maximum altitude vs. launch altitude for various payload weights

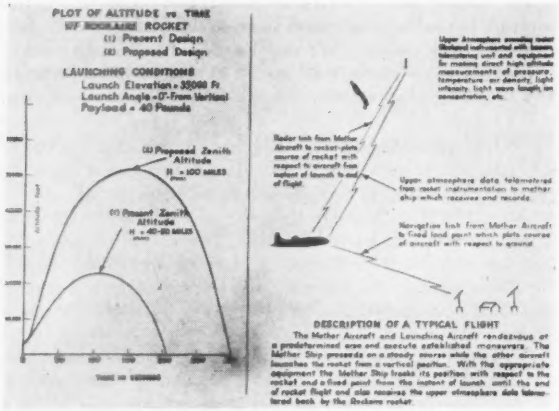
PLOT OF ALTITUDE vs TIME
(1) Present Design
(2) Proposed Design
LAUNCHING CONDITIONS
Launch Elevation = 35000 Ft
Launch Angle = 0°-From Vertical
Payload = 40 Pounds
(2) Proposed Zenith Altitude
H = 100 MILES
(1) Present Zenith Altitude
DESCRIPTION OF A TYPICAL FLIGHT

Fig. 5 Data links required for complete operation

The Nike-Cajun Sounding Rocket

(*Continued from page 268*)

which is ejected from the rocket at 180,000 ft on the up-leg. Ambient density is calculated from the drag equation. The required velocities are obtained by correcting free-fall velocities with the measured drag accelerations. The method requires telemetering only, which is accomplished with a small pulse transmitter radiating at 400 mc from a slot mounted in the sphere. It is not necessary to track the rocket or to measure or maintain any particular angle of attack. The nose cone of the experiment is shown in Fig. 9. The sphere can be seen in the lower portion.

In addition to the above experiments, the State University of Iowa will fire 16 Nike-Cajuns at Churchill with instrumentation for measuring cosmic rays and auroral radiations. The Naval Research Laboratory will launch 16 Nike-Deacons at Point Mugu during the IGY. The NRL rockets will carry detectors for measuring x-rays during solar flares. Finally, the New Mexico College of Agriculture and Mechanic Arts is using the Nike-Cajun in its project of photographing hurricanes on the east coast.

The work with solid propellant sounding rockets is just starting. Interesting developments with slow burners, truly small rockets, and very high altitude rockets will be completed soon. In the meantime, the Nike-Cajun will make its contribution to the International Geophysical Year as a proven, reliable vehicle of moderate performance, moderate cost, and simple operation.

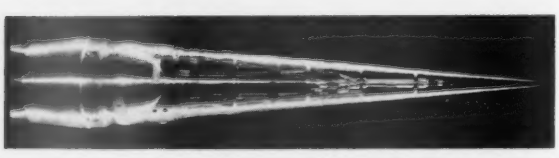

Fig. 9 Sphere Instrumentation used in first Michigan Nike-Deacon and Nike-Cajun

Terrapin—An Upper Atmosphere Research Vehicle

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University of Maryland, College Park, Md. Republic Aviation Corp., Farmingdale, N. Y.

Terrapin is a 220-lb high altitude vehicle consisting of two solid propellant rocket motors. Its low weight and cost together with ease of handling make it a desirable tool for extensive upper air research. The characteristics of the vehicle and of the instrumentation are described in this paper.

Introduction

DURING the initial test firings at Wallops Island, Va., in September 1956 the Terrapin two-stage rocket carried a $6^1/_2$ lb payload to a peak altitude of over 400,000 ft. The launch angle was 75 deg; peak velocity, reached at second-stage burnout, was 6000 fps.

Terrapin represents a successful attempt to devise a light-weight, low-cost simple-to-assemble-and-launch, high altitude sounding rocket. It was developed on a modest budget. At the same time, a thorough engineering analysis was made of its aerodynamics, weight and balance and structural design; every effort was concentrated on keeping drag and weight at a minimum in order to achieve maximum altitude.

The instrumentation package for the initial launchings was tailored to the vehicle—miniaturized and compactly assembled to fit within the sharply pointed nose cone. Weighing $3^1/_2$ lb, it measured two temperatures, acceleration, spin rate, and cosmic ray intensity. The data was telemetered; no recovery system was employed.

Whereas Terrapin was originally planned around two standard solid propellant rocket engines, the T-55 and the Deacon, a new booster case was subsequently developed so as to permit welding the tail fins to it. This saved several pounds in weight.

The Terrapin sounding rocket was developed under contract DA 49-170-SC 1775 for upper atmosphere research held by the University of Maryland. The Guided Missiles Division, Republic Aviation Corp., was one of several companies invited to submit a proposal, based on a general specification for a two-stage design with coast period following NACA practice, and which included an altitude capability of 400,000 ft with a 6-lb payload. Studies were initiated in July 1955. A number of promising configurations were investigated before the T-55–Slow Deacon combination was selected. Republic Guided Missiles assumed responsibility for development and fabrication of the vehicle, including nose cone and zero length launcher, while the University of Maryland Physics Department undertook the development of the instrumentation, including telemetry, its packaging within the nose cone, and ground telemetering equipment. There was continuous consultation between the two groups during this period.

The Bureau of Ordnance and its Allegany Ballistics Laboratory facility cooperated in developing the Terrapin booster. Thiokol Chemical Corp. Redstone Division made minor modifications to the T-55 motor cases to permit attachment of nose cone, tail fin assembly, and coupling. Hercules Powder developed the time delay squib which fires the second stage rocket at +26 sec.

Received January 30, 1957.

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[2] Guided Missiles Division.

Description

Terrapin is 177.33 in. long, has a maximum diameter of 6.25 in. and weighs 224 lb at launching (Fig. 1). A tapered coupling joins the first and second stages, reducing down from 6.25 at the booster to a diameter of 5.93 in., the OD of the T-55 case. The conical nose section has a cone angle of 11 deg. The four booster tail fins are 45-deg clipped delta surfaces machined from aluminum alloy plate. Span is 26.25. The four second-stage fins are of constant chord, swept at 45 deg, and have a span of 19.93 in. They are machined from 8740 steel and welded to a cylindrical section which fits over and is fastened to the nozzle adaptor. A boat tail section covers the booster nozzle, aft of the fins, to reduce drag. The first-stage fins are interdigitated at an angle of 45 deg with respect to the second-stage fins, in order to main-

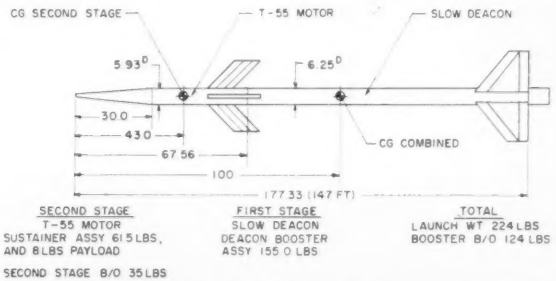

Fig. 1 Terrapin—two-stage high altitude research rocket

Fig. 2 Terrapin on launcher

tain a low downwash influence. Two button-type launching lugs, 84 in. apart, are welded to the booster case.

The coupling joining the two stages consists of male and female sections. The former is riveted to the T-55 tail fin assembly and fits over the skirt of the nozzle. The latter is bolted to the forward end of the booster case. Correct orientation of the two stages is established during assembly on the launcher. Two pip pins, 180 deg apart, are inserted into reamed holes through the joined sections of the coupling. They are removed after the rocket is in position and ready to fire.

The welded tubular steel zero-length launcher is built in six sections (Fig. 2). It is readily assembled by bolting the sections together, and is provided with levels and leveling lugs. The launch angle may be varied by increments of 5 deg from 45 to 90 deg. The two tension members are provided with hinged joints which permit pivoting the launcher to a horizontal position. The booster is placed in position by fitting the two lugs into notched supports. The second stage is then coupled to the booster, as previously described. The time-delay squib for firing the second stage rocket engine is wired in parallel to the booster igniter. The assembled Terrapin is then swung up through the vertical to the predetermined launching angle and the hinged joints in the tension members are locked with pins.

Design Criteria

A detailed discussion of the development of design criteria for Terrapin is beyond the scope of this paper. Only a brief, generalized one is presented. It is significant to note, however, that the predicted performance showed good agreement with the flight test data obtained by NACA and reviewed in a following section.

Trajectory calculations indicated that a small increment in the vehicle drag coefficient would reduce the maximum altitude attainable by a significant number of feet. A conscious effort was therefore made to keep the design clean. Supersonic drag coefficients were calculated on the basis of nose cone wave drag, body base drag, body skin friction drag and fin form drag, using methods verified by wind tunnel tests, firing tests, and free flight tests.

Three trajectories for Terrapin were computed where the firing time of the second stage was varied. It was concluded that the second stage should not be fired earlier than 26 sec from ground takeoff, but that an error of ± 2 sec in timing would not penalize the vehicle's altitude performance.

Aerodynamic load calculations were developed based on a cross wind velocity of 30 fps. Body normal force coefficients were obtained from wind tunnel test data of similar configurations. Fin normal force was based on two-dimensional supersonic flow corrected for sweep, tip losses, body fin interference, downwash, and aeroelastic deflections.

Since, at the time the design was under development, the payload weight had not been determined, the decrement in maximum altitude for several increments in payload weight was computed.

Rocket Instrumentation

Instrumentation used in the initial Terrapin rockets was designed to be of a general type and useful for a variety of experiments. A supporting instrumentation must always include a power supply and a telemetering system, except, of course, for experiments in which optical observations are made from the ground. Additionally, the initial Terrapin rockets carried a Geiger counter, to measure the cosmic ray intensity as a function of altitude, as well as several instrumentations for verifying and testing out the performance of the rocket. These included an accelerometer, a spin-rate meter and temperature gages at two points of the rocket instrumentation. Fig. 3 shows a block diagram of the telemetering section.

The telemetering system used is of the FM/FM type and incorporates five channels to transmit the detected data. The telemetering system was completely transistorized with the exception of the 215 mc transmitter which utilized vacuum tubes because of the frequency and power required.

The transistorized subcarrier oscillators were of the Colpitts type. The outputs of the oscillators were linearly added to generate the complex audio signal used to modulate the transmitter. Three methods for frequency modulation of the subcarrier oscillators were incorporated and provide for modulation from either a voltage variation, resistance variation, or an inductance variation. The resistance control method effectuated a 15 per cent deviation in frequency for a resistance change of 0 to 1500 ohm. The resistance control method was incorporated with measurements of the spin rate and the temperature while the voltage control method was used for the cosmic ray channel.

Although originally the accelerometer was to be of a type that provides a variable resistance for modulating the subcarriers, the accelerometer actually used was of the variable inductance type. This variable inductance was applied directly to the oscillator tank circuit to modulate the subcarrier oscillator. Since the maximum cosmic ray intensity anticipated is of the order of 25 counts per sec, a scale factor stage was incorporated between the Geiger tube and the cosmic ray subcarrier oscillator to reduce the relayed counting rate by a factor of 32. By utilizing a d-c output from the scalers that alternates between two levels for every 32 counts received, the intelligence frequency is reduced to about 1 cycle per sec maximum. Thus counting rates can be recorded on a standard pen recorder at the ground station. The scale factor stage consists of five transistorized scale-of-two, bi-stable circuits in cascade to provide the required scale factor with a d-c output.

The complete 5-channel transistorized telemetering section (excluding transmitter) operated from -15 v dc with a power consumption of less than 1 watt. The combined audio signal supplied to the modulator was about 10 volts peak-peak.

On the power supply the philosophy adopted was to provide only one battery for the sake of reliability and for the sake of rapid change in case of battery failure. The B+ supply was produced by means of a transistorized d-c converter. Four types of power were required for the system:

B+ for transmitter: 240 v dc at 55 ma
B− for transistor circuits: -15 v dc at 60 ma
A− for filaments: -12.6 v dc at 250 ma
High voltage for Geiger tube: 900 v dc at 1 mu a.

This power was all provided from one battery of 15 v dc. The battery is of the silver-zinc construction and provides a 15 v dc at 2 amp for 20 min.

The Geiger tube voltage and the transmitter plate voltage were provided by the transistorized d-c converter. The Geiger tube high voltage was obtained by adding a separate winding to the step-up transformer to provide the voltage with negligible power drain.

The function of the missile antenna system is to accept RF power from the telemeter transmitter and radiate this power in the most efficient manner. Two fundamental antenna systems from which to choose were available—notch and split-shell. The latter was selected in the interest of simplicity. The point of feed was moved as far forward as practical so as to maximize the down-tilt of the antenna pattern. It was moved so far forward that it was possible to represent the system with a high degree of accuracy by a long, thick linear antenna.

As far as is known, this is the first high altitude research rocket in which the instrumentation was fired in a non-pressurized condition, i.e., with the skin of the rocket not pressure tight. Obviously this has great advantages from

an operational point of view and the philosophy in the whole design has been to keep the operational problems of the rocket launching very much down so that these launchings can be made easily and rapidly. A nonpressurized interior allows the nose cone to be removed and put back on again rapidly, permits putting holes in the nose cone for optical windows, and reduces the loads on the nose cone and the problems of accurate and tight fitting. Careful packaging of the instrumentation enabled it to stand at least 300 g.

The greatest problem for this type of high altitude rocket is likely to be temperature. A minimum heat transfer between the skin and the instrumentation was provided through proper radiation shielding. The other new feature adopted in the thermal design of the instrumentation was heat sinks which act to delay the rise of temperature.

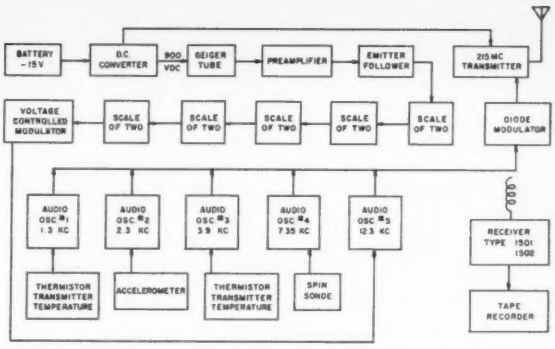

Fig. 3 Instrumentation block diagram

Flight Test and Performance

The following are excerpts from the preliminary report on the first test firings of Terrapin. Permission was granted by the NACA to include pertinent sections of the report in this paper.

Two Terrapin vehicles were fired at the NACA Pilotless Aircraft Research Station, Wallops Island, Va., on Sept. 21, 1956, for the purpose of proving the structural integrity and checking the performance of the vehicle.

Internal instrumentation was provided by the University of Maryland as well as a mobile receiving station, used to receive the telemetered data. The facilities provided by the NACA included an SCR-584 tracking radar unit which provides slant range, azimuth, and elevation angle from which the horizontal range, altitude, and flight path angle may be obtained. A rawinsonde was used to provide data on atmospheric conditions such as static pressure, temperature, density, and wind velocity. The C. W. doppler radar unit obtains the velocity of the model with time. The velocities thus obtained were then used with the speed of sound, as calculated from radiosonde measurements, to obtain Mach numbers.

Drag coefficients were obtained during test flights by evaluating the expression

$$C_D = -\frac{w}{qgS}\left(\frac{dV}{dt} + g \sin \gamma\right)$$

where V = velocity as obtained from C. W. doppler radar and corrected to the tangential velocity along the flight path and for winds at altitudes traversed in flight, w = missile weight in pounds, q = dynamic pressure in lb/sq ft, S = body reference area in square feet, dV/dt = acceleration of the missile's center of gravity, and γ = angle which the velocity vector of the rocket makes with the horizontal.

The first Terrapin vehicle was fired at an angle of elevation of 75 deg, and the second stage was boosted to an altitude of 9000 ft at a velocity of 2700 fps. The vehicle was then allowed to coast, and the burned out booster drag-separated from the second stage. Due to some malfunction, the second stage did not fire. The second stage continued to coast to a maximum altitude of approximately 53,000 ft at 55 sec after ground launching. The horizontal range upon impact was approximately 38,000 ft. However, performance and structural integrity of the first stage were proved, and also drag data were obtained on the second stage. The second Terrapin vehicle was launched at an angle of 75 deg but the angle dropped slightly immediately after launching. The second stage was boosted to an altitude of approximately 8200 ft at a velocity of 2750 fps. The vehicle then coasted and the first stage separated. After 26 sec from ground launching time, the second stage accelerated to a maximum

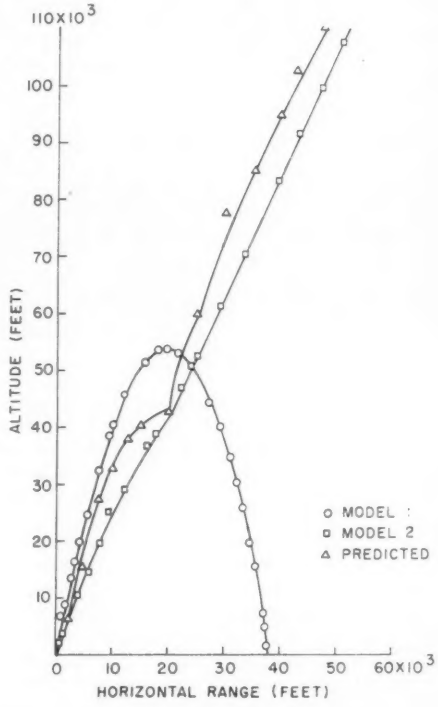

Fig. 4 Flight trajectories

velocity of 5680 fps. Radar contact was lost at 146,000-ft slant range. Comparison of available data with the predictions supplied by Republic Aviation Corp. shows good agreement.

The trajectories of both vehicles are shown in Fig. 4 as well as the predicted trajectory obtained from Republic Aviation Corporation, Missiles Division. Fig. 5 shows the plots of altitude as a function of time for both vehicles as measured by radar contact and also the predicted curve of altitude vs. time. The variation of velocity with time during the first-stage boost and the second-stage coast for both vehicles is shown in Fig. 6. Fig. 6 also includes the variation of velocity with time of the second-stage boost and coast period for model number 2 as well as the predicted values from ground launching to impact for the Terrapin vehicle. The velocity of the second-stage powered flight was obtained from the SCR-584 radar data. These data are sufficient for determining the performance but are not of sufficient accuracy to calculate the drag coefficients. Fair agreement was obtained between the calculated and measured values of the drag coefficients.

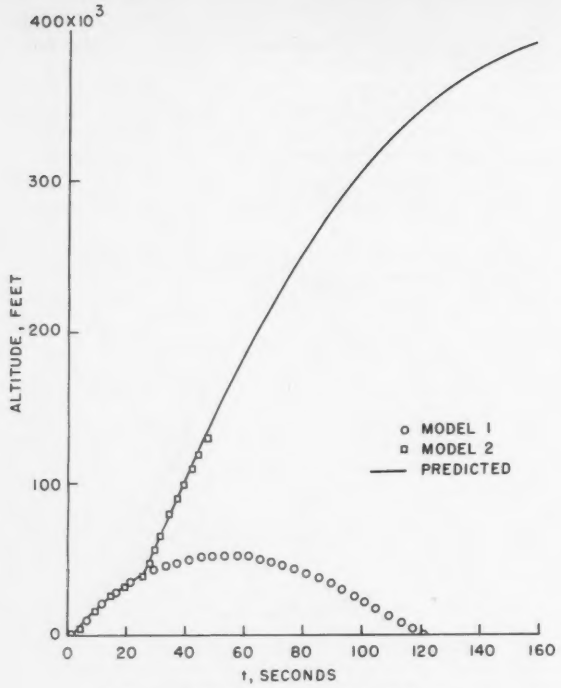

Fig. 5 Variation of altitude with time

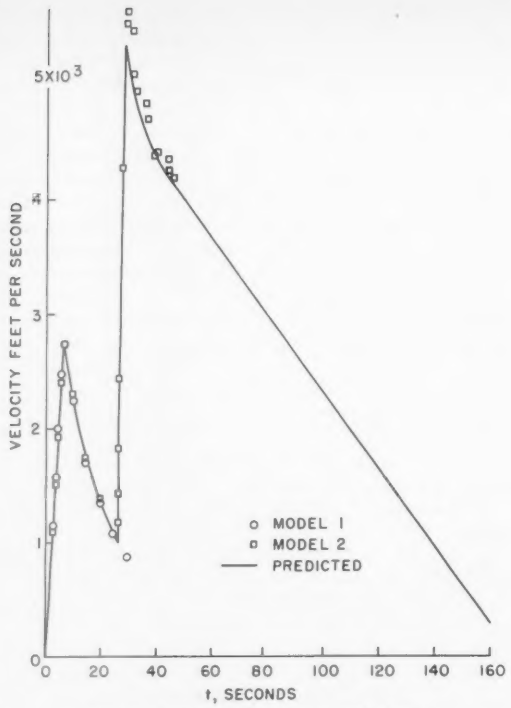

Fig. 6 Variation of velocity with time

Future Programs

Several new programs are under development for Terrapin. These include studies of micrometeorite frequency and impact intensity, the creation and observation of artificial meteors, gaseous refraction tests, and the measurement of solar photons in the ultraviolet and x-ray regions during a solar flare.

The various payloads for these projects vary in weight and volume, requiring some modification of the nose cone structure. The nose cone angle remains unchanged, but a cylindrical section is added when space requirements make it necessary. In the case of the micrometeorite studies, polished surfaces are to be exposed at a pre-set altitude on this upward leg of the trajectory, covered over on the downward one. The nose cone is then recovered by parachute. The artificial meteors consist of shaped charges to be fired from the nose cone near zenith, while the refraction tests are made by observing the sun's rays refracted from sodium vapor clouds, at sunset or just before sunrise.

The solar radiation experiments will consist of firing a series of Terrapins on a programmed time basis, each from a separate launcher, during an observed solar flare. By photographing the solar flare on a time sequence basis and correlating the flare eminence with the frequency of the telemetered solar photon count, the effective variation in radiation can be established in relation to the prominence of the flare.

Conclusion

It is submitted that there is a definite place in upper atmosphere research for the small, high altitude, solid propellant rocket. Preliminary analysis of a modified Terrapin configuration, in which the Cajun motor is substituted as a first stage, indicates that this vehicle would be capable of carrying a 25-lb payload into the ionosphere; there would be no significant change in weight or cost. Analysis of another configuration weighing less than 100 lb indicates an altitude capability of 150–200 miles with a 5-lb payload.

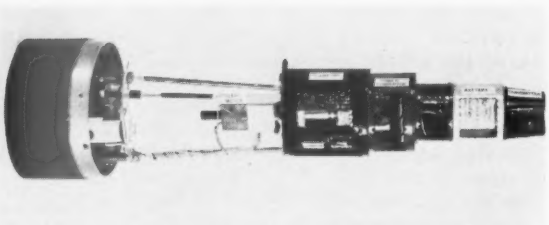

Fig. 7 A sectionalized photograph of instrumentation

Certain experiments require more elaborate instrumentation, which present weight and volume problems. However, the need for statistically significant upper atmospheric information of certain types requires the quantitative accumulation of data. Because of the high over-all cost per launching of the larger sounding rockets and the elapsed time and manpower required, the gathering of quantitative data must be restricted to the smaller, lower-cost vehicle.

The restrictions placed by a vehicle such as Terrapin on the scientist, to confine his upper atmosphere research instrumentation to small volume, low-weight payloads, is challenging. However, the tremendous strides made in the miniaturization and subminiaturization of electronic and electromechanical components and precision mechanisms furnish him with many reliable devices which can be used to achieve compactness and minimum weight.

The premium placed on ingenuity in small payload instrumentation for specific upper atmosphere research projects pays off. The vehicle to transport the instrumentation can be small and low in weight. Its cost is proportionately less. Because it is small and light, its components require no elaborate handling gear, can be lifted and assembled by a ground crew of two or three people. Test site assembly time can be a matter of minutes. Since favorable surface weather conditions are desired for launching, such a vehicle can be readied for flight quickly, after the passage of a storm, or disassembled and stowed should the phenomena to be

(*Continued on page 288*)

The French Missile Veronique

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Veronique, originating from V-2, has four delta-shaped fins. The propellants are nitric acid and turpentine. The weight, before firing, is one ton. The guidance at launching is realized with a special device. The telemetering system has 20 channels. Of the 15 rockets which have been fired, the maximum height reached is 135 km.

VERONIQUE is a French rocket developed by the Direction des Etudes et Fabrications d'Armement of the Ministry of National Defense in the Laboratoire de Recherches Balistiques et Aerodynamiques, at Vernon (Eure), 80 km from Paris.

This missile originates from the German V-2, but offers several unusual features, for example, the four delta-shaped fins. Its length is 24 ft; its diam 1.8 ft; its weight at launching, 1 ton; it may carry a payload of 60 kg distributed into a volume of 100 liters. At the end of the propulsion period, the weight is only 350 kg.

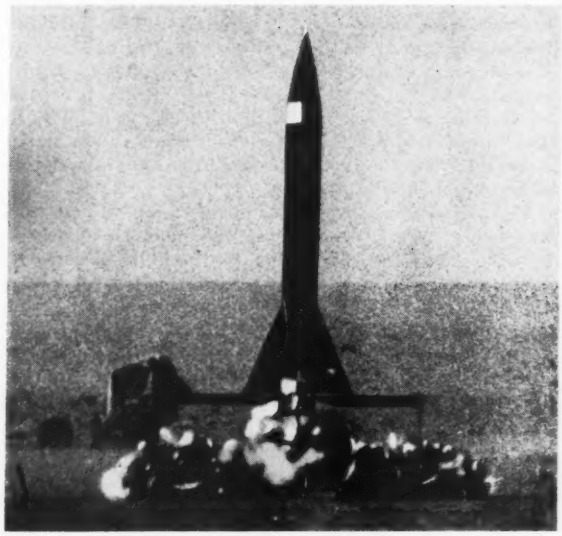
The propellants used, the weight of which is 700 kg, were fuming nitric acid and Diesel oil, fired by a hypergolic igniter consisting of furfuryl alcohol. Recently, excellent results have been obtained by using turpentine.

The propellants are contained in two tanks, made of steel plate and placed with the acid tank in front of the fuel tank. The filling of the tanks is done under a pressure of about 50 kg/cm². To do so, hot gases are injected into the tanks. These gases come from chemically neutral liquids and are free from water vapor to avoid the annoyances of condensations. Therefore, a small combustion chamber has been added; it is made of steel, and cooled by circulation between double walls of a third liquid which is injected into the combustion gases at the outlet of the chamber.

The injector, which atomizes and mixes the propellants, has one plane wall facing the firing place and upon which are distributed small conic craters; on this wall abut two nozzles, one for each of the propellants.

The guidance at launching is obtained in the following way: A wooden cross is fastened to the four fins of the missile with the aid of explosive bolts. A cable is fixed at the tip of each arm of the cross. A second cross, of the same size, attached to the launching platform, bears a guide-pulley at the tip of each arm, and the four cables wind around a single drum with vertical axis. The tensions of the cables being calculated so that they balance the disturbing forces, this device brings about a vertical launching of the missile. When the stabilization is sufficient, the fixing bolts explode and the rocket follows its flight without its cross. If it be desired that the missile trajectory make an angle with the vertical, the drum must be properly profiled.

The telemetering system was devised to transmit 20 measurements coming from potentiometric pickups. The carrier frequency is 152 Mc/s; the information signals appear as uniformly spaced impulses, the intervals being 950 μ sec, the duration between 100 and 750 μsec, with a 4 msec interruption. This blanking allows the necessary time for synchronization at the receiver, and consequently the extraction of information by a counting device.



Veronique ready for launching

At the ground, the time modulation is converted to an amplitude modulation by two different methods:

1 Modulation of the Wehnelt cylinder (control grid) of a cathode-ray tube by the information signals; a synchronized saw-tooth is connected to the vertical plates.

2 After decoding by the electronic switch, the information signal has a variable duration and a fixed amplitude; it goes through an integrating cell to the amplifier of the coil recorder. A memory device, consisting of a magnetic recorder, is added to the whole equipment.

Thirty-five pieces of information are transmitted per second, which limits the pass-band to about 5 cps. The quarter-wave aerial completes the duralumin cone in which is located the telemetering equipment; the total weight is 6 kg; the power, 2 w.

To date 15 Veroniques have been fired in North Africa. Typical performance and trajectory characteristics are the following: maximum altitude, 115 km reached 175 sec after takeoff; maximum speed, 1400 m/sec at burnout time. The maximum height ever reached was 135 km, on February 21, 1954.

Since the end of 1954, the firings have been stopped, owing to financial difficulties encountered by the French National Committee for the International Geophysical Year. At the instigation of the Comité d'Action Scientifique de Défense Nationale, the researches have been undertaken again by different military offices, apart from the IGY. Several improvements, especially the quality of the metal used to make the tanks, lead us confidently to expect better performance than in the former firings.

In addition to Veronique, the Comité d'Action Scientifique de Défense Nationale has at its disposal the powder rocket ATEF, a three-stage missile of smaller size, which has reached an altitude of 80 km and which is in the course of development. An even higher ceiling is expected from future improvements.

Presented at the ARS 11th Annual Meeting, New York, N. Y., Nov. 26–29, 1957.

[1] Professor; Director, Atmospheric Physics Laboratory.

The Japanese Sounding Rockets

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The Japanese Science Council has two projects for the International Geophysical Year, 1957–1958, Sounding Rockets Program, namely, Kappa and Sigma Projects. The objective of the Kappa Project is to make a multistaged, solid propellant, ground launched rocket capable of climbing to 80 miles altitude with a payload of 15 lb. The Sigma Project aims to develop a Rockoon system, with a small rocket of about 25-lb weight, and a peak altitude of between 55 and 65 miles.

The approach to the final Kappa rocket took two steps. The first step was to fire the miniature size test missile, Pencil rocket. As the second step a little larger sized rocket, called Baby, was tested. With Baby rockets, a firing range was set up, optical and radar tracking systems, telemetering, and recovery of data were studied, and field crews were trained.

Three Kappa rockets were fired successfully in September 1956, attaining a speed of Mach 2.7. Kappa with boosters will be tested in March and April of 1957. In 1956 two preliminary tests for Rockoon were carried out to study the balloon launching from a ship on the ocean, to measure the change of temperature of the rocket propellant during the balloon ascent, and to check the operation of the pressure sensitive ignition systems. The launching of Rockoons with live rounds is scheduled for April and May 1957.

Introduction

IN JANUARY 1955, the National Science Council of Japan decided to participate in the upper atmosphere observations by sounding rocket during the International Geophysical Year, 1957–1958. A Special Committee for the Sounding Rocket Program was organized in the National Science Council, and research funds are being supplied by the Japanese Government, the budgets of 1955 and 1956 being $140,000 and $200,000, respectively.

The Committee decided upon two projects for IGY: Kappa and Sigma Projects. Kappa is a ground launched, multistaged, solid propellant, single instrumented, sounding rocket. Sigma is a Rockoon project. Twenty Kappas and the same number of Rockoons are scheduled to be fired in IGY, although the exact number of actual firings will depend on the budget of the 1957 fiscal year.

The research started in February 1955, and most of the efforts to date have been concentrated on obtaining the rocket vehicle. Since all aeronautical research activities had been stopped during the occupation, we had no kind of rocket vehicle with which to start.

The static test stands for rocket motors were built first, and researches began in the field of solid propellants.

In April 1955, the first miniature size rockets, the Pencil rocket series, were fired for basic study. In August 1955, larger rockets, called Baby rockets, were launched. In September 1955, telemetering and tracking systems were studied by firing six Baby-T rockets. In October and November 1955, three Baby-R rockets were fired to study the technique of data recovery from the ocean. Then, finally, the Kappa rocket was designed and ground based tests continued until August 1956, after which, in September 1956, three Kappa rockets were launched successfully.

Presented at the ARS 11th Annual Meeting, New York, N. Y., Nov. 26–29, 1956.

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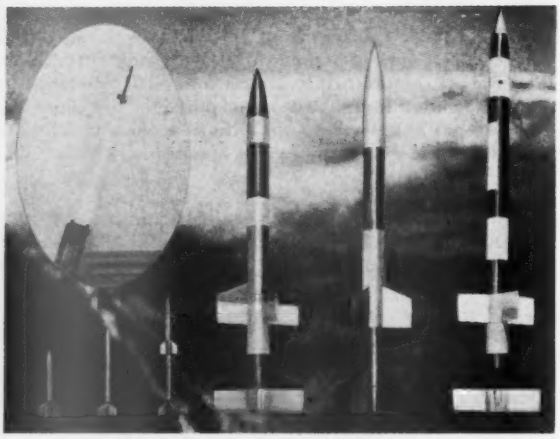

Fig. 1 Pencil and Baby rocket series

In the coming December 1956, four Kappas with instrumentation are scheduled to be fired, and in March and April 1957 Kappas with boosters are supposed to climb up to 80 miles with 15 lb of payload.

Along with this Kappa program, preliminary tests of a Rockoon system were conducted in 1956, testing the launching of balloons from the ship, measuring the temperature change of the rocket propellant during the balloon stage, and checking the operation of a pressure sensitive ignition device for the rocket.

The Pencil Rocket Series

The Pencil rocket (Fig. 1) may be the smallest test missile in the world. Its length varies from 9 to 12 in., its diameter is 0.7 in., and its weight is below half a pound. Its speed is subsonic to transonic. The rocket is tested both in a horizontal range and at the test field.

Pencil rockets have been used as follows:

1 To study correlation between center of gravity location and dispersion.

2 To study correlation between launcher length and dispersion; from the rocket's behavior the thrust misalignment was computed.

3 To compare various nozzles and propellants.

4 To study the effect of tail fin configurations; as an extreme case some Pencil rockets were fired without tail and without launcher.

5 To train optical tracking personnel; simulation for larger rockets was achieved by generating the proper angular velocities by means of a similarity law.

6 To study multistaging systems; sometimes booster motions after detaching from the main rocket were studied for safety in the field firing of later rockets.

7 To check launching systems; any new type of launch for a larger rocket is always tested by simulation with the Pencil rocket.

So far, more than 150 Pencil rockets have been manufactured and fired. The cost of each Pencil rocket is $15, including everything.

The Baby Rocket Series

As the second step in the Kappa Project, we made a little larger solid propellant rocket, called Baby (Fig. 1). The main features are: outside diameter, 3 in.; weight of propellant, 2.2 lb. The Baby series includes three types: Baby-S, Baby-T, and Baby-R. S means simple; T denotes telemetering; and R indicates recovery. Baby rockets attain transonic speeds.

With aluminum tail fins and plastic nose cone and body, the over-all length of Baby-S is 3.28 ft, excluding one short booster. Baby-S was intended mainly to train field experiment crews, to develop facilities for rocket firing tests, tracking equipment, launching systems, etc. As Japan does not have any desert area, we have had to use the ocean for a rocket range. Therefore, cooperation with the Coast Guard and the Fisherman's Union has been an important factor in Baby-S firings. Six Baby-S rockets were fired in August 1955. The rate of spin was as low as one revolution for each 5 sec, and the dispersion was less than the computed value of 4.3 deg, deduced from Pencil rocket tests.

Along with the development of Baby-S, various methods of computing the climbing performance of high altitude sounding rockets were studied, such as step by step or iteration methods, expansion by series, and a velocity-altitude phase diagram. The last one is based on the solution of the equation of rocket motion by an isoclinic method, and is now our routine method of computation.

A telemetering system for sounding rockets was first studied by using Baby-T. Six Baby-T's were fired in September with four instruments: speed, acceleration, pressure, and skin temperature meters. The transducers of these instruments were mostly liquid-resistance type, and provided outputs of 0 to 5 volts dc to the transmitter.

The rocket-borne transmitter was an FM-FM, 4-channel unit, radiating at 414 Mcs, with subcarrier frequencies of 2.5, 3.3, 4.5, and 6.2 kcs. With a wire antenna, the output was 0.1 watt.

Baby-R was designed in order to study the technique of recovery from the ocean. Its over-all length was 4 ft, and a 16-mm rocket-borne camera was the thing to be recovered. This rocket is separated into two pieces after the summit by a pyrotechnic method using a timer. Then the rocket-borne camera together with its parachute and self-inflating float are ejected by explosive. Dye marker helps the aircraft and helicopter find the point of impact.

The camera, specially prepared for Baby, has a length of 7.4 in., diameter 2.9 in., and weight 0.16 lb. Two pictures can be taken per second, with a shutter speed of $^1/_{300}$ sec. The camera has a 23-mm, f-3.5 lens. Two out of three cameras were successfully recovered in October and November 1955 at the Akita test field.

The Kappa Rocket

We have now reached the stage of designing and firing the Kappa rocket (Fig. 2). Twenty Kappa rockets are scheduled in IGY to observe air pressure, solar radiation, ion density, cosmic rays, temperatures, and winds in the upper atmosphere. The diameter of Kappa is 5 in.; length, 7 to 8 ft. Three Kappa rockets without boosters were launched at Akita in September 1956, and the maximum speed was approximately 2800 fps, Mach 2.7. A 5-ft launcher was used.

The next Kappa flight will be in December 1956, with four kinds of instruments, and a telemetering system. A combination of a bellows and inductance-type transducer will produce d-c voltages from pressure ports at the nose and along the rocket body, and will determine the Mach number. The second instrument will be an accelerometer to measure acceleration during and after burning in order, by integration, to get the altitude attained. The third will be a skin temperature meter, of which two types have been prepared.

Fig. 2 Kappa rocket on launcher

Fig. 3 Akita rocket test field of Tokyo University

One of these is a fuze type, in which metals of various melting points are made and attached to the skin, and the skin temperature is then measured stepwise by telemetering the opening of the fuzes. The last instrument will be a wire strain gage, which will measure the stresses in the tail fin in the sandwich construction we use.

Both optical and radar tracking have been prepared. Six homemade theodolites and two fixed cameras of sector-type exposition are used. The tracking radar is a simple one, and uses a rocket-borne transmitter at 1680 Mcs and a receiving station on the ground. A DOVAP system is also under construction, to operate at 40 Mcs, and will be available in March 1957.

The telemetering for Kappa rockets operates at 225 Mcs. It is an FM-FM, 5-channel system, and uses a body-type antenna, whereas the radar beacon uses a notch antenna in the tail fin.

For the Kappa Project a theoretical study of multistaged rockets was carried out, and a theory to determine the optimum coasting duration for a multistaged rocket was developed. From a velocity-altitude diagram the optimum coasting time can be obtained using a chart based on the theory.

Kappa rockets with boosters are scheduled to be fired in March and April 1957, and are supposed to climb up to 80 miles altitude with 15 lb of payload.

All the Kappa rocket firings will be conducted at the Akita Test Center (Fig. 3), which is located in northern Japan,

facing the Sea of Japan. The main facilities already constructed are: horizontal and vertical test stands, a control room, an instrumentation laboratory, a telemetry station, a radar station, and launchers. This facility was specially prepared for the IGY by the University of Tokyo, and belongs to the University.

Rockoon

Following the original idea of Dr. Van Allen, twenty Rockoons are scheduled in IGY (Fig. 4). In 1956 preliminary tests were conducted using dummy rockets. The first test was performed on September 18, 1956, in order to select a proper ship for IGY. The Weather Observing Ship Ryofu-maru was chosen, and balloons with dummy rockets were launched over the Pacific Ocean. The rocket weight was 22 lb, and two types of balloons were tested. One was a plastic balloon, of 27,000 cu ft; the other was a cluster of seven rubber balloons. Both were successfully launched from the ship.

Fig. 4 Plastic balloon with Sigma rocket climbing aside Mt. Fuji—preliminary Rockoon test in November 1956

On November 19 and 20, 1956, the next preliminary tests of Rockoon were carried out, to measure the change of the rocket propellant temperature during the balloon climbing stage, and also to check the performance of the pressure sensitive ignition systems for the rocket. The data were telemetered, and the final temperature of the rocket motor at 82,000 ft was −8 C for a white-painted rocket, and was 20 C for a black-painted one. This time the Rockoons were launched from the ground close to Tokyo.

Rockoons with live rockets will be launched in April and May 1957, on the Pacific Ocean, and are expected to go to between 55 and 65 miles altitude.

The High Altitude Sounding Rocket

(*Continued from page 262*)

however, still leaves the smaller rockets, like the Deacon and the Cajun, as the only truly inexpensive vehicles at present available to the upper air researcher. Both the Deacon and the Cajun are an order of magnitude less expensive than the Aerobee. This has the great advantage of bringing upper air rocket sounding within reach of universities and other private organizations, permitting skills and know-how in this field to be developed on a broader basis than would otherwise be possible.

It must, however, be pointed out that the price of the rocket vehicle is only a part, and sometimes a small part, of the total cost of an upper air research firing. The research instrumentation, logistic and operational support, and personnel costs, often add up to much more than the purchase price of the vehicle. It will doubtless long continue to be true that all upper air sounding groups, both government and private, will require the logistic and operational support of military firing ranges and ships.

Sounding Rockets in Current Use

Some of the rockets that are being used today for upper air research are:

Aerobee	Nike-Deacon
Deacon	Nike-Cajun
Cajun	Rockoon
ASP	Veronique
Monica	

In its Aerobee-Hi version, the Aerobee will carry 120 lb to several hundred kilometers altitude. When launched from the ground, the Deacon and Cajun do not exceed balloon altitudes, but when first boosted by the Nike booster they can carry 25- to 50-lb payloads to from 80 to 100 kilometers altitude, thus reaching the vicinity of the E-region of the ionosphere. A comparable performance can be obtained by launching these rockets in the stratosphere from a Skyhook balloon. The ASP is a small vehicle with similar uses and capabilities. Both the Veronique and the Monica are French rockets. The former is similar to the Aerobee in concept and size, while the latter is a smaller solid propellant rocket.

England is preparing to use a solid propellant rocket, comparable to the Aerobee, for upper air research during the International Geophysical Year. Japan is preparing a multistage vehicle called the Kappa rocket for IGY, and a version of Rockoon called Sigma.

Finally, for historical purposes, one should mention the WAC Corporal, the V-2, and the Viking, although these are no longer in use for upper air research sounding. A modified form of the Viking, however, is to be used as the first stage in launching artificial satellites for geophysical research during IGY.

Terrapin—An Upper Atmosphere Research Vehicle

(*Continued from page 284*)

measured fail to materialize. With the few available test site facilities being taxed by the variety and number of rocket and missile test programs, the portable launcher permits clearing the test site immediately upon the completion of a launching, making it available for other programs.

What is probably of more significance is the fact that upper air soundings need not be restricted to established test facilities. The small instrumented rocket makes it logistically possible for a team composed of a few scientists and technicians to conduct upper air soundings over any uninhabited sea or land area on a synoptic basis.

Acknowledgments

Appreciation is acknowledged for the cooperation of the many individuals who have contributed to the development and testing of Terrapin. These include personnel from the Bureau of Ordnance and Allegany Ballistics Laboratory, Thiokol Corporation, Redstone Arsenal, and the engineering department of Republic Guided Missiles Division. Special thanks are due to personnel of the PARD Division of NACA, Langley: J. Shortel, William O'Sullivan, William Krieger, and R. Hopko. The development of the instrumentation was largely carried out by R. Bettinger, R. Elton, and C. Reber, graduate students of the University of Maryland.

British High Altitude Rocket Research Program

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A high altitude rocket is being developed in the U. K. by the Ministry of Supply for a joint research program between the Royal Aircraft Establishment and a number of universities. The vehicle is 25 ft long, 17½ in. in diam and employs a solid propellant motor. When launched near the vertical, it is expected that an altitude of 490,000 ft will be achieved with a payload of 65 lb. Later flights with a boost addition are hoped to reach 700,000-ft altitude. The missile is stabilized by three fins but it is not guided during flight and will carry telemetry, doppler, and beacon tracking equipment in addition to the payload. The first trainable launcher has already been installed at the Australian rocket range at Woomera and firings will begin there early in 1957.

THE British Ministry of Supply is developing a high altitude rocket vehicle to be used in a program of upper atmosphere research undertaken jointly by the Royal Society and the Royal Aircraft Establishment of the Ministry of Supply. The Gassiot Committee of the Royal Society will supervise the contributions of several British universities. The main contribution of the Royal Aircraft Establishment is the rocket vehicle itself.

The vehicle has been named "Skylark." In outward form it resembles Aerobee, being 25 ft long, 17½ in. in diam, and having 3 stabilizing fins. On the earlier vehicles the fins will be of a type which has been used on other projects; the leading and trailing edges are swept back and the area is sufficient to give ample margin of stability. On later vehicles a lighter and smaller fin of trapezoidal shape will come into use after suitable proving trials.

Internally, the Skylark is very different from Aerobee, because it is powered by a solid propellant motor. The motor has been given the code name "Raven" and is still undergoing development. It is 15 ft long and gives a thrust of about 11,500 lb for about 30 sec. The effects of variations in charge shape are now being examined in order to achieve an optimum thrust-time relationship.

The nose of the Skylark consists of a conical portion 65 in. long and a parallel portion 30 in. long, the latter containing a telemetry sender, a doppler tracking transponder and the microwave beacon of the missile tracking system. This is a system installed on the Australian range in which direction-finding antennae at ground stations lock on to a beacon in the missile. It is anticipated that aerodynamic heating on the nose cone may restrict the choice of material to stainless steel. Both the nose cone and the telemetry bay, which incidentally affords further payload space, may be pressurized independently, and various re-arrangements of the structure will be made from one vehicle to the next to accommodate various experiments; for example, the ejection of grenades from the telemetry bay, or the jettisoning of the forward portion of the conical outer casing.

The Skylark will be launched from a trainable launching tower, some 80 ft high. The tower is supported near its midpoint by a tripod structure carrying a gymbal frame on which there are 2 sets of gymbals which afford movement between 15 deg forward of the vertical and 5 deg rearward of the vertical in the elevation sense, and 10 deg either side in azimuth, and the tower is power operated by remotely controlled driving motors mounted on the gymbal frame. The loading trolley is incorporated in the frame of the tower and the whole structure weighs some 30 tons; it has been constructed mainly from army engineers' bridge panels. The launcher rails have been made adjustable so that the launcher could, if desired, accommodate Aerobee; it will also be possible with slight adjustment to fire Skylark from the Aerobee launcher at Fort Churchill. The first launcher has now been erected at the Australian rocket range at Woomera where the Australian Government Department of Supply is cooperating with arrangements for the firings.

Since the Raven motor is still in its development stage, it is not possible to give precise performance figures, but Skylark No. 1 will be potentially capable of a maximum altitude of 490,000 ft with a payload of 65 lb. However, for reasons of safety, this first vehicle will be fired at an elevation of 75 deg (15 deg forward of vertical), the prime concern being with the launching behavior of the vehicle and its flight to "all burnt"; consequently a comparatively low ceiling is expected. Every effort has been made to launch Skylark No. 1 before the end of 1956, but at the time of writing it appears that this will not occur until 1957. It will be understood that the great distance between the place of manufacture and the firing range does cause some special difficulties in the firing of experimental vehicles.

In choosing the Raven motor the advantages of using liquid fuel motor have been sacrificed for the simplicity of operation and relative cheapness of the solid propellant motor. The Skylark, as originally conceived, is a single-stage vehicle, and in that form a high initial thrust is necessary to give a launching speed high enough to reduce dispersion to a satisfactory amount. The motor, having this characteristic, will not give maximum performance as measured by peak altitude, and for this reason it is not expected that altitudes of 400,000 ft will be exceeded in the early firings.

In order to achieve high altitudes and to overcome the dispersion problems at launch the need for a boost motor is recognized, and it is expected that late in 1957 a version with a short-period boost motor will be provided at Woomera. This boost should reduce the dispersion substantially and make possible a maximum altitude in the region of 700,000 ft.

With these developments in mind, it has been considered worth while to begin preparations for the firing of a version of Skylark from a test range within the United Kingdom. This test range is operated by the Royal Aircraft Establishment and is situated on the west coast of Wales, firing into the sea between Britain and Ireland. In the event that the firings at Woomera show that the point of impact is predictable with reasonable certainty, part of the research program will be transferred to the United Kingdom range.

On the assumption that the Skylark proving trials proceed satisfactorily in the first half of 1957, flights with the equipment provided under the Royal Society research program should begin in Australia with the commencement of the International Geophysical Year. The following is a list of the experiments which have been proposed and for which in-

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Presented at the ARS 11th Annual Meeting, New York, N. Y., Nov. 26–29, 1956.

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Technical Notes

Hydrogen Peroxide Field Analyzer

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A field method was developed to measure the concentration of hydrogen peroxide in aqueous solution in the range of 70–90 weight per cent hydrogen peroxide. The hydrogen peroxide solution flows through a granular catalyst bed and the temperature of the gaseous decomposition products is measured. The apparatus is calibrated against titrated hydrogen peroxide concentration. Standard error of measured data is less than 0.05 per cent hydrogen peroxide.

Nomenclature

c_l = specific heat capacity of liquid, cal/°C gm (H_2O_2 solution)
c_p = specific heat capacity of gas, cal/°C gm
$\dot{m}$ = mass flow rate, gm/min
q^- = heat loss rate, cal/min
S = standard error; $S = \sqrt{\Sigma (W_c - W_o)^2/n}$ where n = number of data
T_{id} = adiabatic decomposition temperature of H_2O_2 solution of 20 C initial temperature
t_{in} = inlet temperature of H_2O_2 solution, °C
T_{20} = measured decomposition temperature at 20 C inlet temperature, °C
W_o = true concentration of aqueous H_2O_2 solution in weight per cent H_2O_2 as found by titration

Introduction

THE goal of development was a field method to measure the concentration of hydrogen peroxide solutions of 70–90 per cent hydrogen peroxide by weight. A precision of ±0.1 per cent hydrogen peroxide was required. Equipment was to be rugged enough for field use; procedure, simple enough to be learned by unskilled personnel after a few demonstrations.

A survey of all methods proposed for hydrogen peroxide analysis (1)[3] showed the following methods in competition for a field method:

1 Titration with permanganate solution.
2 Refractometry (immersion).
3 Density measurement by hydrometer.
4 Density measurement by Westphal balance.

Literature data on refractive index and density are based on permanganate titration. Titration, in turn, was compared with measurements of the volume of oxygen evolved in decomposition of hydrogen peroxide (2) with which it agreed within 0.02 per cent hydrogen peroxide. Accepting the oxygen-volume method as absolute, the titration can be called "near-absolute."

In the experiments of (1), method 2 yielded results 0.2 per cent lower, methods 3 and 4 up to 1 per cent higher than titration. Titration, however, appears not to be suited for the field due to the need for an analytical balance and great cleanliness.

Thermometric Field Method

A method of measuring the temperature of the gaseous products of near-adiabatic decomposition of hydrogen peroxide solutions flowing through a bed of solid catalysts and relating this temperature to the titrated hydrogen peroxide concentration was perfected. A total of 230 tests were run on various configurations of apparatus and variations of procedure.

The apparatus described in the following section has given the best results and is considered to be mature for field application.

Description of Apparatus

The apparatus consists of the three separate components listed in Table 1.

The sample container is a polyethylene bottle of 3-liter volume with a drain tube of the same material, a rubber bag with a rubber bulb pump and connecting tubing, carried in a case

Table 1 Main components of apparatus

Component	Weight, lb	Base Area, in. × in.	Height, in.	Estimated price in production of 1000 units
Sample container	11	8 × 8	16	$ 40.00
Decomposer	7	5 × 6	12	40.00
Potentiometer with thermocouples	12	7 × 11	7	420.00

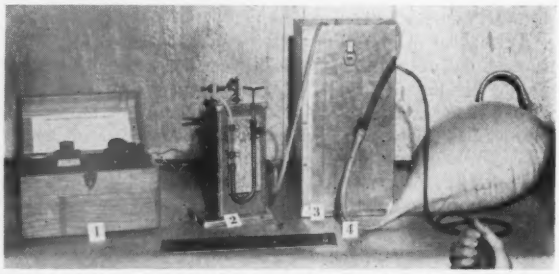

Fig. 1 Apparatas ready for test—1) potentiometer, 2) decomposer, 3) sample container, 4) air pressure bag

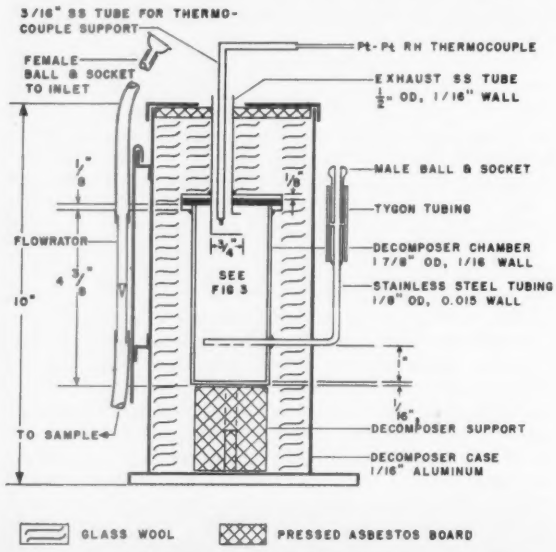

Fig. 2. Sketch of decomposer

Received June 18, 1956.
[1] Chief, Combustion and Fuel Laboratory. Mem. ARS.
[2] Chemist, Combustion and Fuel Laboratory.
[3] Numbers in parentheses indicate References at end of paper.

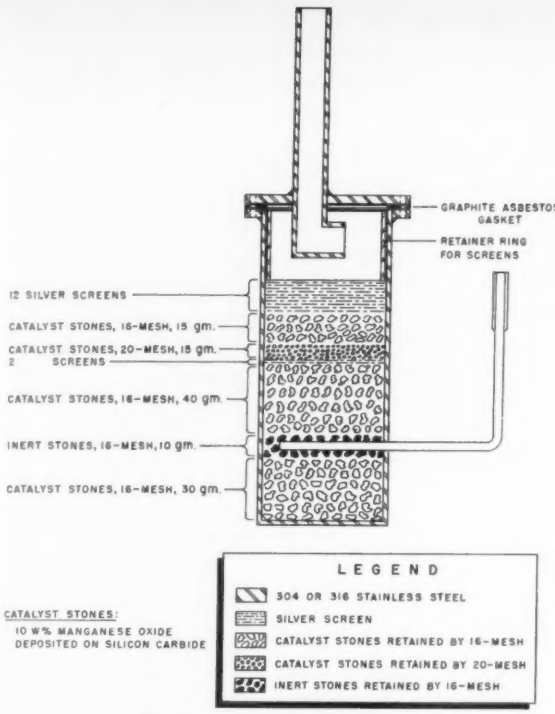
GRAPHITE ASBESTOS GASKET
RETAINER RING FOR SCREENS
12 SILVER SCREENS
CATALYST STONES, 16-MESH, 15 gm.
CATALYST STONES, 20-MESH, 18 gm.
2 SCREENS
CATALYST STONES, 16-MESH, 40 gm.
INERT STONES, 16-MESH, 10 gm.
CATALYST STONES, 16-MESH, 30 gm.
LEGEND
304 OR 316 STAINLESS STEEL
SILVER SCREEN
CATALYST STONES RETAINED BY 16-MESH
CATALYST STONES RETAINED BY 20-MESH
INERT STONES RETAINED BY 16-MESH
CATALYST STONES:
10 W% MANGANESE OXIDE DEPOSITED ON SILICON CARBIDE

Fig. 3 Decomposition chamber

of aluminum (see Fig. 1). A drain tube ends in a female ground-glass joint, fitting its counterpart on the decomposer unit.

The decomposer is described by Fig. 2. The decomposition chamber (Fig. 3) is embedded in a glass wool insulation contained in a carrying case. A flowmeter and a Weston thermometer is mounted on the outside of the case, intruding into the feed stream to indicate the sample inlet temperature.

A potentiometer from Leeds and Northrup, designated "8663 special," covers a range of temperatures from 280 to 880 C with 1 C being the scale unit. The potentiometer has a compensator for changes of ambient temperature, thus obviating the need for an ice bath as temperature reference.

Test Procedure

A peroxide sample of at least 2 liters is placed in the sample bottle; the glass joint is connected to the counterpart on the decomposer and held tight by a spring clamp. The thermocouple leads are connected to the potentiometer. The rubber bag is inflated by the hand pump while the pinch cock is closed. Then, the pinch cock is gradually opened until the desired flow rate is reached. The flow rate is held at this level, indicated by two limiting marks, by occasional boosting of bag pressure by means of the bulb pump.

After 12 or 14 min (see Table 5), the operator begins to read the temperature every minute for 3 min.

The test is terminated by releasing the bag pressure by lifting the polyethylene stopper. The pinch cock is closed after the liquid column has regressed to the sample container.

For disassembly, only separation of the ball joint and thermocouple lead wires is needed. Covers are replaced on the units to ready them for carrying.

It takes 5 min to set up the apparatus, 15 min to run the test, and 5 min to disassemble—a total of 25 min.

Theory of Method

Hydrogen peroxide is readily decomposed by certain catalysts according to

$$(H_2O_2)_{liq} = (H_2O)_{liq} + \tfrac{1}{2}\,(O_2)_g + 12{,}930 \text{ cal } (25°C, 1 \text{ atm})$$

The gas temperature, which is obtained by complete adiabatic decomposition of aqueous hydrogen peroxide solution, is a function of the initial temperature of the solution t_{in} and the concentration of hydrogen peroxide W. Data can be represented by

$$T_{id} = 25.40\,(W_o) - 1545 \quad [1]$$

and, conversely $$W_o = 60.83 + 3.937\left(\frac{T_{id}}{100}\right) \quad [2]$$

The correction for deviation of inlet temperature from 20 C standard is readily obtained from a heat balance

$$c_1 \cdot \Delta t_{in} = c_p\,\Delta T \quad [3]$$

Inserting data for c_1 and c_p from (3), we obtain an average value of

$$\frac{\Delta T}{\Delta t_{in}} = \frac{c_1}{c_p} = 2.00 \quad [3a]$$

which holds with an accuracy of ±0.6 per cent over the range of 70–90 per cent hydrogen peroxide.

Combining [1] and [3a] gives

$$T_{id.t} = 2540\,(W_o) - 1545 + 2.00\,(t_{in} - 20) \quad [4]$$

Deviation of Measured Temperature from Theoretical Value

Heat Loss Through Insulation: It is obvious that there will be heat losses from the apparatus due to imperfect insulation. Magnitude of these losses was estimated from measurements of surface temperatures of the decomposer case during long operation. The heat loss rate was calculated from common heat transfer formulas, taking into account the surface area, surface position, temperature and velocity of ambient air, etc. Results are presented in Table 2.

The per cent hydrogen peroxide "lost" by heat dissipation was found from

$$\Delta\, W\%\ H_2O_2 = \frac{q^-\left(\frac{\text{cal}}{\text{min}}\right)}{c_p\left(\frac{\text{cal}}{\text{gm}\cdot°\text{C}}\right)\dot{m}\left(\frac{\text{gm}}{\text{min}}\right)25.4\left(\frac{°\text{C}}{W\%\ H_2O_2}\right)} \quad [5]$$

Other heat losses influencing the measured temperature are those from the thermocouple. These errors were estimated by heat transfer calculations.

Table 2 Heat losses from decomposer estimated from surface temperature measurements

(Flow Rate 100 gm/min)

$W\%$ H_2O_2 inlet	Wind veloc. mph	Ambient temp, °C	Surface temp, °C			Heat Loss Rate $\frac{\text{cal}}{\text{min}}$, q^-	Absolute error $W\%$ H_2O_2
			Top	Sides	Bottom		
75	0	26	50	42 ± 1	40	150	−0.15
75	5	26	42	35 ± 1	34	278	−0.27
90	0	25	119	120 ± 1	96	945	−0.87

Table 3 Estimated error of temperature measurement

Error = $T_{meas} - T_{ideal}$ with 90 weight per cent hydrogen peroxide solutions

Radiation error	−0.05 C
Conduction error	−0.01 C
Recovery error at 0.7 recovery ratio (Exhaust Mach number: 0.15)	−1.0 C

The only significant error is the error due to the low recovery ratio, estimated (4) to be only 0.7, of a bare wire thermocouple. This could, of course, be improved by using a cup-type thermocouple. But, it appears to be irrelevant since it amounts to only 0.04 per cent hydrogen peroxide, and, moreover, is reproducibly included in a calibration.

Heat Gain of Feed Stream: Heat is transferred from the insulation material through the feed tube to the liquid. In order to minimize this gain, the part of the feed tube traversing the insulation was made as short as possible and as narrow as tolerable with respect to pressure drop.

The maximum heat gain for the apparatus shown in Fig. 2 was estimated, from a heat transfer calculation based on measured temperatures of the insulating material, to be equivalent to less than 0.05 per cent hydrogen peroxide.

Calibration of Apparatus

Procedure: An empirical calibration of the apparatus with titrated hydrogen peroxide concentration as the basis was the only way to account for heat loss and gain.

Various concentrations of hydrogen peroxide were prepared by diluting 90 per cent hydrogen peroxide solutions with distilled water. Analysis samples were taken immediately preceding the test run and directly from the sample bottle. Three gas temperature and inlet temperature readings were obtained at the 12, 13, 14 min or 14, 15, 16 min, respectively, depending on time elapsed between tests, and averaged. These readings were reduced to 20 C inlet temperature using [3a].

Calibration Equation: From the data the best-fitting straight line was calculated by the method of least squares.

The standard error of experimental points with respect to this straight line was found to be

$$S = 0.092\%\ H_2O_2$$

Although this would be an acceptable precision, it can readily be improved by accounting for the slight curvature of the function through the use of two linear functions, one for low and one for high concentrations. This decreased the standard error to only $S = 0.025\%\ H_2O_2$.

Compromise on Test Duration and Flow Rate

Fig. 4 shows a plot of temperature readings vs. time of operation at two flow rates, starting with a cold or warm decomposer.

Here, "cold" means that the decomposer was near room temperature (first run of the day); "warm" means 20 min after preceeding run.

It can be seen that the temperature reaches a practical equilibrium after 14 min of operation with the "warm" start and higher flow rate. Proposed reading intervals, indicated by 3 arrows, were selected to read temperature within 2 C (= 0.1 per cent H_2O_2) of equilibrium. By standardizing on a certain time interval of warm-up and another of reading (3 min), it was possible to obtain reproducible results.

If the apparatus was cold at the beginning of the run, results would come out too low as Fig. 4 shows. This error can be compensated by increasing the warm-up interval. The intervals shown in Table 4 were standardized.

A high flow rate tends to shorten the warm-up interval,

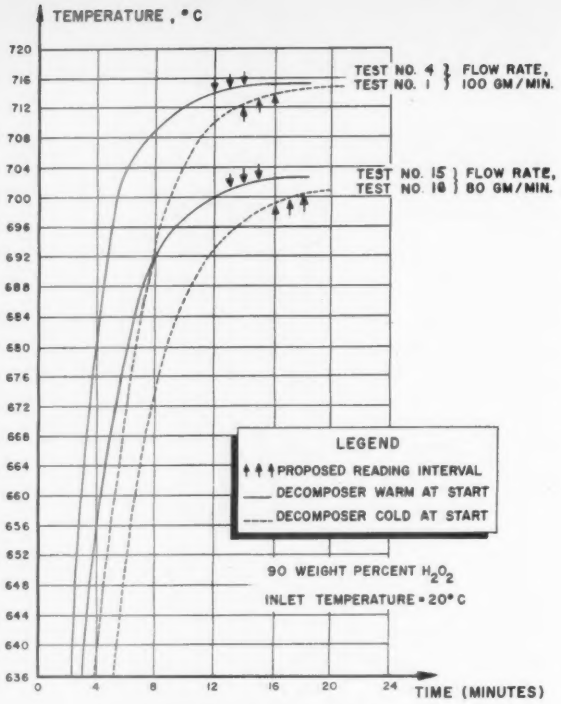

Fig. 4 Decomposer exhaust temperature vs. time

Table 4 Reading intervals at flow rate 75 ml/min

Thermocouple inside decomposer reads before test →	Below 280 C	Above 280 C
Interval to first reading	14 min	12 min
Interval between three consecutive readings	1 min	1 min

but is limited by the necessary stay time in the catalyst to produce practically complete decomposition. Overloading of the catalyst was indicated by a sputtering discharge and by yellow spots on titanium sulfate paper held over the discharge opening indicating hydrogen peroxide. A flow rate of 75 ml/min (= 100 gm 90 per cent H_2O_2) was found satisfactory with the described configuration.

Low Ambient Temperature

Some tests were run in the open at temperatures of 1.2 C to 22 C. Results agreed with titrated hydrogen peroxide concentrations with standard error of 0.07 per cent which is well tolerable.

Testing by Unskilled Personnel

Service mechanics, unskilled in chemical laboratory operations, were able after about two demonstrations to produce measurements matching titrations with standard error 0.05 per cent in 10 tests.

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Leading Edge Cooling

ARTUR MAGER[1]

Marquardt Aircraft Co., Van Nuys, Calif.

Convenient expressions for the time required to reach any specified cylindrical leading edge temperature, or for the coolant flow rate per unit leading edge length, are given. Without cooling, these are applicable to short time deviations from the conditions at which the equilibrium temperature is reached; while, with cooling, level, constant velocity flight is postulated. In both cases, the heat lost by radiation is taken into account.

Nomenclature

B = constant (convection to radiation ratio)
C = specific heat capacity
c = specific heat
D = function of Θ
F, G = functions of θ
H = heat transfer function
h = coolant heat transfer coefficient
Q = heat flow rate
$\dot{q}$ = average aerodynamic heat flow rate per unit area
R = outer radius
r = inner radius
T = temperature
t = time
w = coolant flow rate
x = axial coordinate
y = auxiliary variable
ϵ = emissivity
Θ = coolant to equilibrium temperature ratio
θ = wall to equilibrium temperature ratio
κ = conductivity
σ = Stefan-Boltzman constant
ϕ = time dependent aerodynamic heat flow rate
ω = density

Subscripts

c = coolant
e = equilibrium
f = final
i = initial
p = constant pressure
v = inner wall
w = outer wall
$0, 1, 2\ldots$ = successive approximations
Bar over the value indicates averaging

Introduction

THE advent of very high speed flight has focused attention on the problem of aerodynamic heating. In this connection, it has been shown (1),[2] that by flying sufficiently high, where, due to large ratio between the radiative heat loss and the aerodynamic heat input, one can maintain average equilibrium skin temperatures which are compatible with the allowable stresses of known materials and thus reduce the severity of the aerodynamic heating problem. Still, certain critical parts, like the leading edges of wings, nose cones, etc., whose heat transfer coefficients are extremely large, cannot be cooled by radiation alone and these tend to assume the very high adiabatic wall temperatures.

To overcome this problem, the reduction of the heat transfer coefficient at the stagnation region through blunting is generally advocated. Since the heat transfer coefficient depends in such cases inversely on the square root of the radius of the blunt body (2) and since the drag is proportional to the frontal area, the blunting amounts to a certain sacrifice of the aerodynamic characteristics in favor of the heat transfer problem.

Received Jan. 29, 1957.
[1] Research Scientist.
[2] Numbers in parentheses indicate References at end of paper.

This price, which one has to pay for very high speed flight, can be made less costly if additional convective cooling of the leading edges is considered, or if the dashes into the "forbidden region" are of sufficiently short duration, so that the leading edge has no time to reach the excessively high temperature. The objective of this note is to present somewhat simplified, but closed form, solutions for specified temperature rise of such cooled edges, or for short time dashes.

Analysis

Short Time Dash

This problem is somewhat simpler and therefore will be considered first. The transient temperature rise of a cylindrical leading edge is given by

$$C\frac{dT_w}{dt} = \dot{q} - \sigma\epsilon T_w^4 \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

Here the average aerodynamic heat input rate $\dot{q}$ can be obtained at any given flight speed and altitude by integrating the expressions given in (2) and thus may be considered known. It should be noted that $\dot{q}$ is in general a function of time, but for the preliminary considerations we take it to be a suitably chosen constant. The results of (2) are applicable to laminar boundary layers and unyawed leading edges. If the leading edge is yawed, then an appropriate correction to the heat transfer rate can be applied by using the values cited in (3). Furthermore, it should be pointed out that for a cooled wall the heat transfer rate $\dot{q}$, as given in (2), is independent of the wall temperature T_w.

Defining the wall to equilibrium temperature ratio

$$\theta \equiv \frac{T_w}{T_e} \qquad T_e \equiv \left(\frac{\dot{q}}{\sigma\epsilon}\right)^{1/4}$$

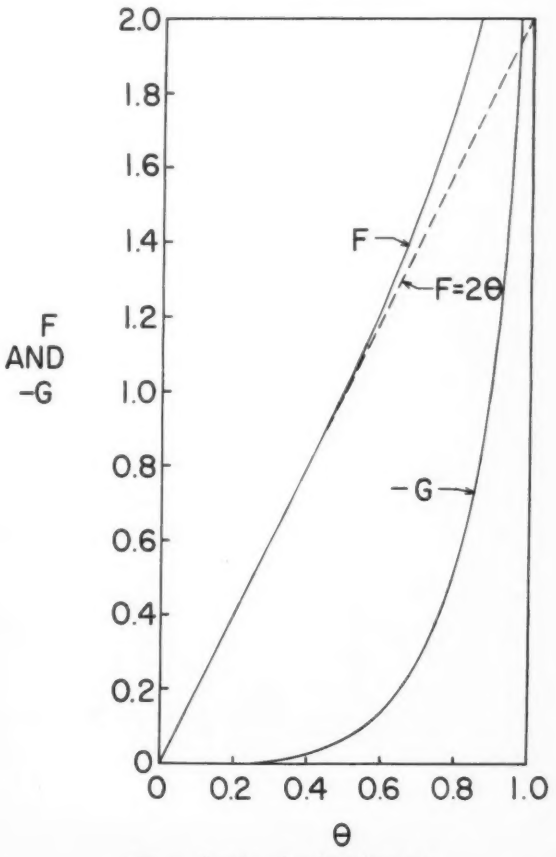

Fig. 1 F **and** $-G$ **as functions of** θ

and remembering that for a solid cylindrical leading edge $C = 0.5R\omega c$ one obtains from Equation [1]

$$\frac{d\theta}{dt} = 2\frac{\sigma\epsilon T_e^3}{cR\omega}(1-\theta^4) \quad \text{[1a]}$$

The appropriate initial conditions may be taken at $t = 0$, so that upon integration one obtains

$$\left.\begin{aligned} t_f &= \frac{cR\omega}{4\sigma\epsilon T_e^3}[F(\theta_f) - F(\theta_i)] \\ F(\theta) &= \frac{1}{2}\log\left(\frac{1+\theta}{1-\theta}\right) + \tan^{-1}\theta \end{aligned}\right\} \quad \text{[2]}$$

The function F is illustrated in Fig. 1. It is easy to show from Equation [2] or see from Fig. 1 that even for quite large values of θ, an excellent approximation to F is given by 2θ. The temperatures $T_{w,f}$ and $T_{w,i}$ are fixed by the allowable stresses of the leading edge material and the initial conditions, respectively. Consequently, the time t_f varies as RT_e^{-4}, or since $T_e^4 \sim R^{-1/2}$, $t_f \sim R^{3/2}$. The decrease of leading edge radius, so as to reduce the drag, will thus limit the permissible dash time. Also, for a given radius, dashes at altitudes much lower than that at which the equilibrium temperature is reached will have to be of rather short duration.

While these considerations are useful for the estimate of over-all trends, in practice, as pointed out above, the aerodynamic heat input will vary with time. For short dashes, however, it should be possible to apply the small perturbation procedure. Taking therefore

$$\begin{aligned} \dot{q} &= \dot{q}_f - \phi; \quad \phi(t) \ll q_f \\ \theta &= \theta_0 + \theta_1; \quad \theta_1 \ll \theta_0 \\ T_{e,f} &\equiv (\dot{q}_f/\sigma\epsilon)^{1/4} \end{aligned}$$

with $\dot{q}_f = \text{const}$, and substituting into Equation [1], one obtains the zeroth order equation for θ_0 which must be identical with [1a] and the first order equation (with nonlinear terms eliminated) for θ_1

$$\frac{d\theta_1}{dt} + 8\frac{\sigma\epsilon T_{e,f}^3}{cR\omega}\theta_0^3\theta_1 = -\frac{2\phi}{cR\omega T_{e,f}} \quad \text{[3]}$$

The initial conditions taken again at $t = 0$ may be conveniently stated as $\theta_i = \theta_{0,i}$; $\theta_{1,i} = 0$. The solution of the zeroth order equation is then given by Equations [2], while the first order equation integrates to

$$\theta_1 = -\frac{2(1-\theta_0^4)}{cR\omega T_{e,f}}\int_0^t \frac{\phi}{(1-\theta_0^4)}\,dt \quad \text{[4]}$$

consequently the wall temperature is given by

$$\left.\begin{aligned} \theta &= \theta_0 - \frac{2(1-\theta_0^4)}{cR\omega T_{e,f}}\int_0^t \frac{\phi}{(1-\theta_0^4)}\,dt \\ \theta_w &= \text{anti } F\left[F(\theta_i) + \frac{4\sigma\epsilon T_{e,f}^3}{cR\omega}t\right] \end{aligned}\right\} \quad \text{[5]}$$

The right-hand side of this equation can be plotted as a function of t, and for any fixed $\theta = \theta_f$ the appropriate time t_f can be found.

Cooled Leading Edge

Here one assumes the leading edge to be made out of a series of cylindrical tubes, placed end to end, each individually reaching the specified maximum wall temperature $T_{w,f}$. Level, constant velocity flight is postulated so that $\dot{q}$ does not vary with time. One can now write the four separate expressions for the heat flow rate

$$\dot{Q} = \pi\kappa dx\frac{T_w - T_v}{\log(R/r)} = \pi r dx\,\bar{h}(T_v - T_c) = \pi R\,dx\,(\dot{q} - \sigma\epsilon T_w^4) = w\bar{c}_p dT_c \quad \text{[6]}$$

These four equations must be valid, at any x, between the four unknowns $\dot{Q}$, T_w, T_v, and T_c. The coolant properties, which were assumed constant, should be evaluated at bulk temperature. Defining the heat transfer function H and the coolant to equilibrium ratio Θ

$$H \equiv 1 + \frac{r\bar{h}}{\kappa}\log\frac{R}{r} \qquad \Theta \equiv \frac{T_c}{T_e}$$

one can show, after some manipulation, that the first three of Equations [6] can be combined into

$$\theta^4 + B\theta - D = 0 \qquad B \equiv \frac{r\bar{h}}{R\sigma\epsilon H T_e^3} \qquad D \equiv 1 + B\Theta \quad \text{[7]}$$

Equation [7] is a relation between θ and Θ, applicable at any x, and can be expressed in differential form as

$$d\Theta = \left(\frac{4\theta^3}{B} + 1\right)d\theta \quad \text{[7a]}$$

On the other hand, from the last two of Equations [6], one also has

$$\frac{d\Theta}{dx} = \frac{\pi R\sigma\epsilon T_e^3}{w\bar{c}_p}(1-\theta^4) \quad \text{[8]}$$

so that using [7a] this finally leads to an equation for the wall temperature θ

$$\left(\frac{4\theta^3}{B} + 1\right)\frac{d\theta}{dx} = \frac{\pi R\sigma\epsilon T_e^3}{w\bar{c}_p}(1-\theta^4) \quad \text{[9]}$$

The appropriate initial condition can again be taken at $x = 0$, so that upon simple integration and rearrangement one has

$$\left.\begin{aligned} \frac{w}{x_f} &= \frac{\pi R\sigma\epsilon T_e^3}{\bar{c}_p}\left\{\frac{1}{2}[F(\theta_f) - F(\theta_i)] - \frac{1}{B}[G(\theta_f) - G(\theta_i)]\right\} \\ G(\theta) &= \log(1-\theta^4) \end{aligned}\right\} \quad \text{[10]}$$

The function G is also shown in Fig. 1. From this figure it is obvious that for reasonably large values of B, such as undoubtedly will occur in actual practice, and even for fairly large θ, the contribution of function G is negligible. Consequently, for fixed $T_{w,i}$ and $T_{w,f}$, w/x_f will vary as $R^{1/2}$. The quantity w/x_f is important because it is proportional to the total coolant flow required for cooling of the fixed length leading edge and thus has an effect on the over-all aircraft performance. For a fixed time of flight, low values of w/x_f signify low weight of coolant on board. One thus notes that a decrease of the leading edge radius will also be favorable from the cooling standpoint. This advantageous situation occurs because while the aerodynamic heat flow rate per unit area increases as $R^{-1/2}$, the total heat flow rate $\dot{Q}$, absorbed by the coolant, decreases as $R^{1/2}$.

It should be noted however that the radius R may not be reduced indefinitely. For very small radii (e.g., small θ), Equation [7] shows that, at each x, the difference between θ and Θ is inversely proportional to B; that is, it increases as the radius decreases. Thus from the initial and final conditions one finds by simple algebra that

$$\theta_f - \theta_i \doteq (\theta_f - \Theta_i) - \frac{1}{B}; \quad \theta \ll 1$$

Since this difference may never become negative, the smallest physically possible value of B is $(\theta_f - \Theta_i)^{-1}$. For this value of B both $\Delta\theta$ and x_f are zero. Consequently, for all radii smaller than the one giving the minimum value of B, the specified $T_{w,f}$ is unrealistic.

As a matter of practical interest, one should indicate the manner in which the actual computations can be carried out. The difficulties occur because neither θ_i, nor $\bar{h}$ are known. If, however, the coolant exit conditions are assumed (it is reasonable to assume $\Theta_{f,0} = \theta_f$), then an appropriate value of

$\bar{h}_0$, based on the bulk temperature can easily be obtained. Using this $\bar{h}_0$, one may compute H_0, B_0; then applying equation [7] at $x = x_f$, one may obtain a new value of $\Theta_{f,1}$. This process can be repeated until successive changes in $\bar{h}$ are small. With values of $\bar{h}$ and B so determined, one obtains the appropriate value of θ_i from the known Θ_i by again using Equation [7]. The solution to this equation may be written explicitly as

$$\left.\begin{aligned} \theta_i &= \sqrt{\frac{y}{2}}\left[\sqrt{2\sqrt{1+\frac{D_i}{y^2}}-1}-1\right] \\ y &= 2\sqrt{\frac{D_i}{3}}\sinh\left[\frac{1}{3}\sinh^{-1}\frac{B^2}{16\sqrt{\left(\frac{D_i}{3}\right)^3}}\right] \end{aligned}\right\} \quad \ldots\ldots [11]$$

With θ_i and θ_f known, the problem is completely determined.

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British High Altitude Rockets

(*Continued from page 289*)

strumentation is now being constructed:

1 Temperatures and winds at altitudes in the range 30–100 km by the grenade method (University College, London). Microphones will be sited at convenient points over a large area. The grenade flashes will be detected by ground based photomultipliers which will be slaved by tracking equipment during daytime firings.

2 Winds at altitudes in the range 20–70 km (Imperial College) by the radar tracking of window (chaff) released from rocket.

3 The sodium vapor experiment (Queens University, Belfast). The sodium emission will be studied by an interferometric method.

4 Day and night airglow (Queens University, Belfast). A group of five photomultiplier tubes will be flown under a jettisonable nose cone, and filters will be used to restrict measurement first to the oxygen green line and later to the oxygen red line.

5 Ion mass-spectrometer (University College, London). A mass spectrometer probe will be carried under a jettisonable nose on an extendable support, and will be used to measure the nature and abundance of atmospheric ions.

6 Absolute concentrations of electrons and ions (University of Birmingham). Details have still to be decided but in principle the proposal is to apply a voltage pulse between two probes and to measure the resulting pulses of electrons and positive ions.

7 Electron densities by radio propagation methods (University College Swansea and Royal Aircraft Establishment). Both a C. W. method based on the doppler tracking system, and a pulse method are being developed for the measurement of electron densities.

8 Pressures and temperatures (Royal Aircraft Establishment). Various types of pressure gages are being developed; whenever possible ram and cone wall pressures will be measured in flight.

The execution of the experiments at Woomera is being made possible by the willing cooperation of the range staff of the Weapons Research Establishment, Adelaide.

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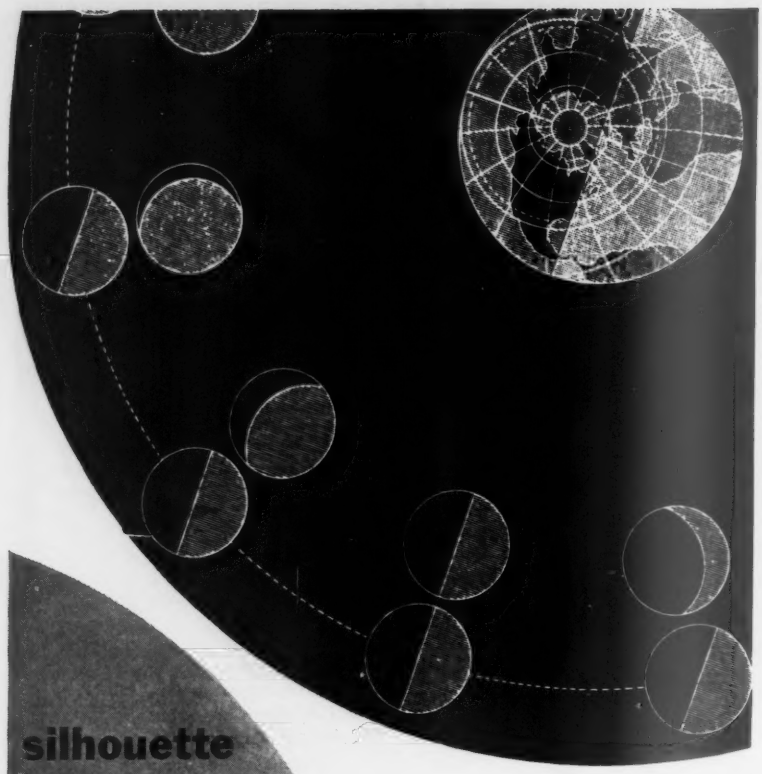
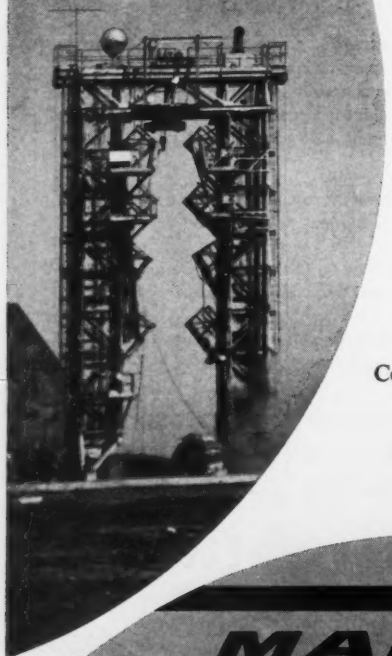


silhouette against the sky . . .



Towering above the American scene, the gantry is not an uncommon sight at rocket research sites. But that same shape silhouetted against the sky near Denver takes on added significance.

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Patrick AFB:

LAUNCHING site of tomorrow's satellites and weapons, Patrick AFB (Fla.) is the biggest missile test center in the United States.

Its tracking range stretches all the way from Station 1 at Cape Canaveral (Fla.) 4400 miles out over the Bahamas, Puerto Rico, the Windward Islands and Fernando De Noronha Island to Ascenscion Island in the South Atlantic about half way between South America and Africa.* The length of the range makes it suitable for testing all big U. S. missiles now under development or planned.

But while the range itself is adequate, some of the range facilities are being pressed hard to keep pace with the ever-increasing demands now being placed upon them.

Miles per Ton: Consuming chemicals at rates like six tons/minute, for example, the new missiles are straining Patrick fuel facilities to the limit, creating some unusual and major problems in storage, handling, and manufacturing. As witness:

To by-pass a difficult transportation problem, the government built its own liquid oxygen plant at Cape Canaveral. But with the step-up in the U. S. missile program, capacity of the plant —10 tons of lox per day—has already proved too small. Consequently, the government soon plans to build a new and larger lox plant.

Handling the propellants is another ticklish proposition. Most of them are either toxic, corrosive and/or explosive. Eye sprays, emergency showers, match checking, etc., at the change house are only a few of the precautions taken in the propellant area at Cape Canaveral.

In addition, the men that actually handle the propellants are generally sheathed in protective clothing of asbestos and rubber with plastic helmets or visors. While effective, such clothing is usually cumbersome, tends to seriously cut down the wearer's agility.

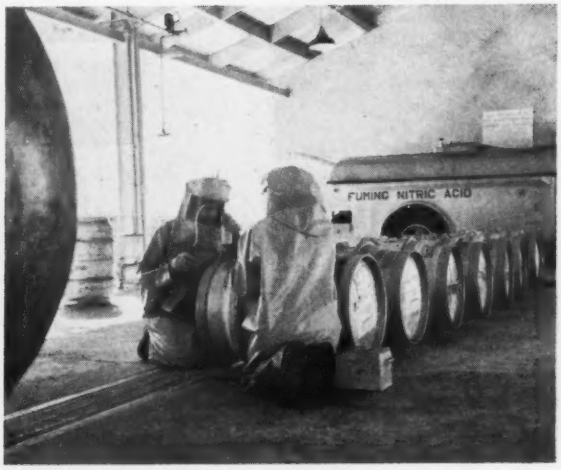
It Costs to Be Safe: Storage of missile propellants is, perhaps, the biggest problem. And, if it is to be done safely, it is expensive.

Propellants handled at the AFMTC fall into two basic groups: fuels and oxidizers. Among the oxidizers currently in use are hydrogen peroxide, liquid oxygen, and nitric acid. The present propellants range from RP-1 (rocket propellant-1, which is a highly refined kerosene) through chemicals such as furfuryl alcohol, aniline, and anhydrous ammonia up to one of the most recent developments, Udetta (a

* Saint Helena, British island in the South Atlantic reportedly available to U. S., would extend range to approximately 5000 miles.

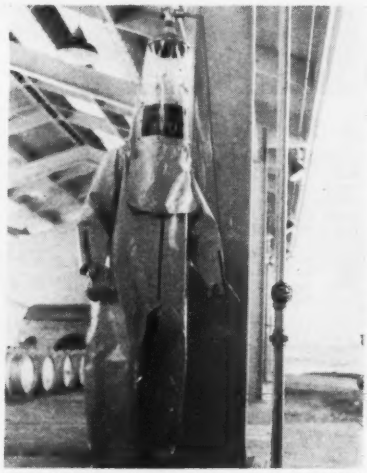
'Gas Station' for Guided Missiles

DISPOSAL OF CONTAMINATED FUEL requires skill and patience. Trainee watches while three experienced men actually do the job.



TESTING FOR CONTAMINATION of propellant goes on constantly. Here, workers take a sample of red fuming nitric acid, an extremely corrosive and toxic oxidizer.

CHECKING HYDROGEN PEROXIDE, worker seeks "hot drums" which must be disposed of before they ignite.



SPILLED ACID MUST BE WASHED away immediately. Drains (beneath iron grills) and hoses are provided in propellant storage areas for spillage while showers are conveniently located for cleaning acid-contaminated clothing.

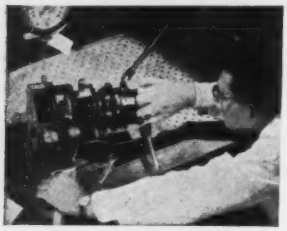
SEVEN SECONDS IS MAXIMUM TIME men have to wash acid out of eyes. Special eye fountains are located near each area where handlers have to work with toxic or corrosive propellants.

LEAVING THE ACID AREA after an afternoon's work, propellant handlers head for the "change house." Here they'll wash, change clothes, and light up that long-awaited cigarette.

TEST EQUIPMENT

The Test Equipment Engineer is engaged primarily in the design of specialized missile check-out equipment. As missiles push the state of the art, test equipment must exceed the missiles in precision and reliability. Automatic programing, go-no-go evaluation, and automatic data processing add up to automation in missile testing.

This engineer is evaluating his design of a precision power supply—one of the building blocks that will be system engineered into a family of versatile matched missile and sub-system test equipment. Engineers work as individuals.



HYDRAULIC DESIGN

Excellent opportunities are available for the engineer to observe the performance of his design. Here, under the watchful eyes of its designer, a hydraulic power unit is undergoing adjustment and setting prior to severe testing at simulated high altitude conditions.

Many components, which a few months ago seemed almost impossible to design, are now being tested under the severe conditions required to qualify them for flight operation—and passing with flying colors.

STEERING INTELLIGENCE

Two Steering Intelligence Engineers discuss space allotment in a new guidance component. This close association of engineers with the "flying" equipment is typical of the Steering Intelligence Section. Engineers in this section are primarily *and directly* concerned with refining the guidance equipment to steer the missile with greater accuracy, at greater ranges and with simpler and more reliable electronic equipment and, consistently, with minimizing the cost. Work is actively in progress in every principal field from microwave equipment to inertial end instruments.

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mixture of unsymmetrical dimethyl hydrazine and diethylene triamine).

Fuels and oxidizers, of course, must be separated from each other and, in some cases, completely isolated. Then there are the solid propellants which also must be set apart. Too, the conditions under which propellants must be stored are sometimes critical.

Red fuming nitric acid, for example, can be stored only in high purity aluminum drums. Ethylene oxide must be delivered and stored under refrigeration at 40 F; at 86 F it breaks down chemically or polymerizes. Hydrogen peroxide is stored in isolated buildings made of steel-reinforced concrete, well ventilated, and with built-in sprinkler systems and drain networks.

Touch and Go! Hydrogen peroxide, particularly, is treated very tenderly at Patrick. Propellant handlers scrub down the peroxide containers each day, and carefully check for what they call "hot drums"—drums in which hydrogen peroxide has started to decompose chemically and generate heat. If not caught in time, this heat buildup would lead to a violent explosion. And all it takes to get this dangerous chain reaction under way is a large speck of dust.

The fact that there hasn't been one major accident at Patrick attributable to propellants in six years of missile operation reflects creditably upon range contractor Pan American World Airways and, in particular, upon the work of the missile propellant section. But with the increased emphasis recently placed on this country's missile program, their work is just beginning.

Harvard Gets New Guggenheim Center

THE Daniel and Florence Guggenheim Foundation has made a $250,000 grant to Harvard University to establish the Harvard-Guggenheim Center for Aviation Health and Safety.

Scheduled to start operations with the beginning of the 1957-1958 academic year, it is the fifth aviation research center established by the Foundation since 1949 and the first to be devoted to problems of health and safety.

Scientists at the new center will study human responses to extreme speeds, altitudes, temperatures and toxic agents, both in flight and on the ground. They will also carry out basic research on prevention and control in these areas.

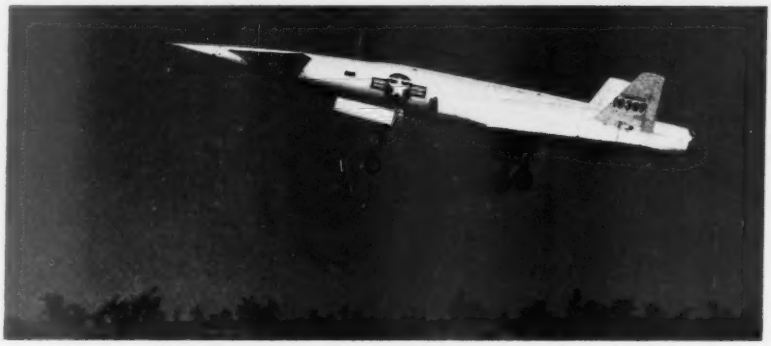
The center will serve to give advanced training to physicians, biological scientists, and aeronautical engineers. In addition, the center will function as a clearing house for technical information on aviation health and safety and will attempt to unify basic research in these fields.

MISSILES MAKE NEWS

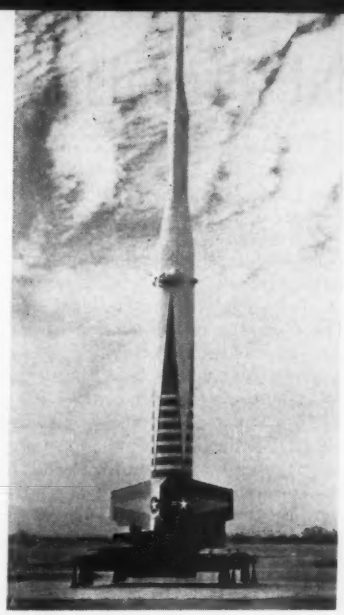
First Pictures . . .

LACROSSE

A solid propellant, surface-to-surface guided missile, the Lacrosse is described as an extremely accurate all-weather weapon. The vehicle, designed for the field artillery to supplement conventional air or ground attack, can be fired from a launcher mounted on a standard army truck with a rapidity comparable to that of a 105-mm howitzer. Army has awarded Martin Co. a production contract for the missile which was designed and developed by Cornell Aeronautical Laboratory, Inc.

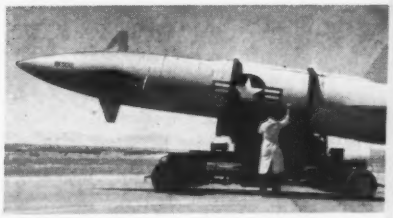


X-10 Along with the first pictures of North American Aviation's X-10 unmanned test vehicle comes word of the conclusion of the flight test program at Patrick AFB. Powered by two turbojets, the X-10 was used to prove out guidance and control systems and aerodynamic design of the rocket-boosted, ramjet-powered SM-64 Navaho, an Air Force intercontinental strategic guided missile. With the conclusion of this test phase begun in 1945, North American is starting operations on the Navaho itself. Designated a surface-to-surface missile, the SM-64 will travel at supersonic speed and very high altitudes.



X-17

Used to obtain data on the critical re-entry problem, the X-17 is a three-stage ballistic rocket which weighs more than 6 tons and stands as high as a four-story building. Produced by Lockheed Aircraft Corp., this test vehicle costs considerably less than the long range weapons it simulates. The vehicle passes through the sound barrier and into the ionosphere "within seconds."



RASCAL

Designed for use against tactical or strategic targets, the GAM-63 Rascal is a long range, rocket-powered, air-to-surface guided missile. An offspring of the Shrike (JET PROPULSION, Feb., Cover), the Rascal is produced for the Air Force by Bell Aircraft Corp.

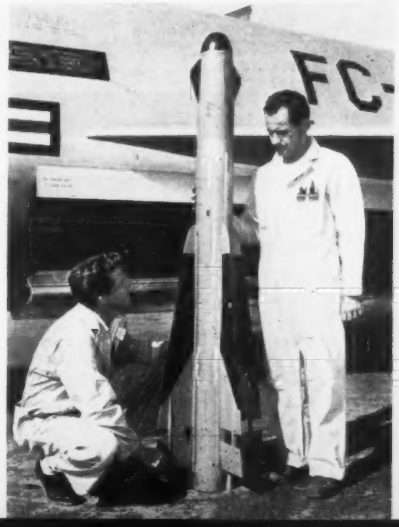
. . . and New Models

MATADOR

Second of the Martin series, the TM-61B is about 5 ft longer, has a greater range and a better guidance system than the original Matador. Moreover, its wings can be folded back, thus permitting it to be towed into action more quickly and easily. Assigned to the Air Force, the new surface-to-surface missile is 44 ft long, 54 in. in diam, and has a wing span of 22.9 ft. It is boosted into the air by a rocket and then powered at 650 mph by a J-33 jet engine.

FALCON

A radar-guided supersonic missile, the GAR-1D is the latest version in the Falcon family of air-to-air rockets. The weapon is designed for use by all-weather jet interceptors against high flying enemy bombers. Slightly over 6 ft long, the Falcon has an air frame diameter of approximately 6 in. and weighs less than the average man. Range of the missile is "measured in miles." Hughes Aircraft Co. is manufacturing the weapon in Tucson.



Ozone: Ominous, Omnipotent

THE advantages of using ozone as an oxidant for rockets were recognized early. But success hinged on a process to make high concentrations safely. The past was full of reports of spontaneous and unpredictable explosions.

Many researchers finally concluded that 100 per cent ozone (as a gas or liquid) couldn't be made, let alone safely handled. But then came a technological break-through and the evidence began piling up: Impurities were causing most of the troubles; get rid of impurities and safe ozone might be possible.

In 1948, Armour Research Foundation joined Linde Air Products and the Air Reduction Co. (Murray Hill, N. J.) in an attack on the problem. The early phases of the Armour work were sponsored by Airco and the U.S. Air Force. In 1955, Armour reported production of 100 per cent gaseous and liquid ozone free of sensitizing elements and compounds.

Although patent proceedings did not permit all details to be revealed, the trick seemed to be in getting pure oxygen to start with, since even so-called pure cylinder oxygen or lox (liquid oxygen) had enough trapped impurities to cause trouble later. Once impurities dropped below 20 parts per million, safe 100 per cent ozone was possible. Moreover, in 1955 Linde was able at last to list the properties of ozone with a fair degree of accuracy (see table: Properties of Ozone).

Process Key: Essentially, the production of ozone rests upon the reaction of three oxygen molecules (O_2) to produce two molecules of ozone (O_3). The energy—34.5 kilocalories per mole of ozone—is supplied in a silent electrical discharge. In commercial ozone generators, oxygen passes over insulated and separated plates charged to about 10,000 volts.

Ozone condenses to form a blue liquid that (unlike liquid oxygen) is nonmagnetic. It has a very pungent odor, which may be detected at a concentration of 1 part per 500 million.

Present applications take advantage of ozone's oxidizing properties; e.g., purification of drinking water, deodorization, bleaching, etc.

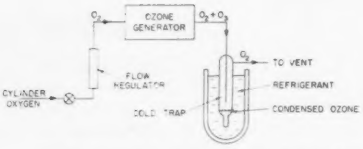
Toxic and Touchy: Unlike oxygen, ozone is toxic in very small concentrations. The safety level for humans working with ozone in industrial applications is considered to be 0.1 part per million. However, in a recent Armour experiment, an Air Force physiologist breathed 8 parts per million of ozone for one hour. He survived but his breathing capacity was reduced about 50 per cent. Severe lung irritation in less than one hour may result in sensitive persons at concentrations of about 2 parts per million. Swelling of the lung tissue starts at about 4-5 parts per million. The conclusion is that even low ozone concentrations can produce harmful effects in humans.

Since the decomposition of ozone into molecular oxygen does not involve combustion, even pure ozone is tough to handle. Ozone mixed with oxygen has only one explosive limit (as opposed to the familiar upper and lower limit for combustibles). This limit is said to depend on the pressure, temperature, shape and dimensions of the container, type and contact surface area, and the exciting energy.

When the temperature is −180 C or higher, the safety limit is about 30 per cent by weight. Above the safety limit, the explosion violence increases. Present belief is that 100 per cent ozone would give the most violent reaction. Handling as a gas or storage in a liquid solvent just hasn't worked out. Oxygen looks like the best "solvent" so far. Above −180 C, liquid ozone and lox are miscible in all proportions.

In the ozone-oxygen method of handling, there are some unusual hazards aside from the ever-present contamination problem. Leakage of oxygen diluent is bad because when the more volatile oxygen evaporates, the ozone concentration fast builds to a danger level. On the other hand, deep refrigeration is also bad since it might lead to separation of phases. Another important problem is shock. Compress a bubble and the liquid might be detonated by a gentle blow. Even in a super-pure system, one small point of contamination could lead to a reaction violent enough to trigger off the whole mass.

Rocket Oxidant? Whether or not enough ozone has trickled from the still to run a rocket motor is anybody's guess. But Armour has always kept in mind the potential of ozone as a rocket propellant. And, among others, North American Aviation's Rocketdyne Division has analyzed ozone's probable performance as an oxidant with JP-4



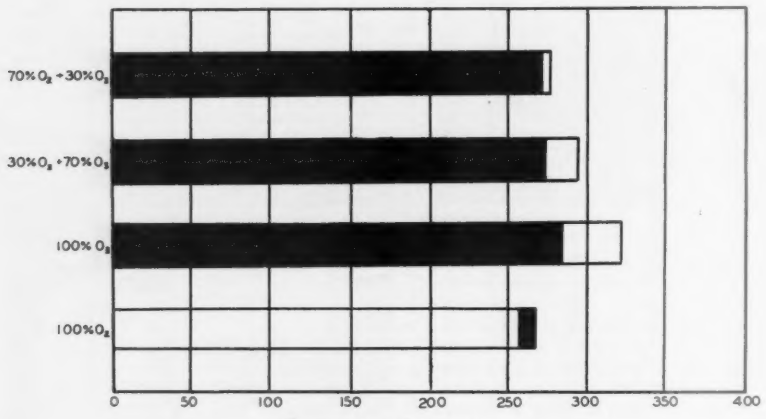
Courtesy of Armour Research Foundation

One way to 100% liquid ozone

Properties of ozone

Boiling point	−111.9 C
Melting point	−192.8 C
Critical temperature	−12.1 C
Critical pressure	54.6 atm (abs)
Density of liquid @ −183 C	1.57 g/ml
Critical solution temperature[1] (in lox)	−179.9 C

[1] Above this temperature, liquid ozone and lox are miscible in all proportions.



Ozone vs. Oxygen

In this comparison of the rocket performance of ozone and oxygen, JP-4 is the fuel considered. Extension of ozone bars represents I_{sp} × density. In the case of oxygen, contracted bar is result of a system density less than 1.

fuel in a rocket motor (see graph: Ozone vs. Oxygen. Ozone's greater density, among other properties, seems to give it a definite advantage over oxygen as an oxidant.)

Air Reduction Co. is also reported to be interested in high concentration ozone. And, Princeton University has been working for almost three years (under an Air Force contract) on an evaluation of liquid ozone-oxygen mixtures as oxidizers for rocket propellants. Most details of the still-active Princeton project are classified.

On the other hand, Linde is convinced ozone has considerable industrial potential but is frankly uncertain about its propellant value. While high purity decreases the probability of detonation, it is by no means a cure-all to ozone problems. Linde still advises handling ozone behind sturdy barriers. And, adds Armour, although safe handling of ozone is now a distinct possibility, more basic work is needed to turn it into an actuality.

And, significantly perhaps, at the Armour-sponsored International Ozone Conference recently held in Chicago, while only one rocket firm, Aerojet-General, was listed as a cooperating company, all major aircraft companies engaged in rocket research were in attendance.

Thus, while ozone seems to hold a great deal of promise as a rocket propellant, it is apparently still too early to measure laboratory promise against operational performance. As one wag observed: You can put ozone in a rocket, but *do not* shake well before using!

MISSILES

• In the proposed budget for Fiscal 1958, President Eisenhower has requested $2646 million in new obligational authority (money authorized by Congress for spending) for guided missiles—approximately $346 million more than the comparable request for 1957. This plus the $331.8 million to be authorized for research and development of guided missiles and related equipment will bring proposed missile expenditures for 1958 to a record-setting $2978 million. (For additional details, see box: More Money for Missiles.)

• International control of the "outer space" missile and satellite development was proposed by President Eisenhower. The proposal is to be submitted to the United Nations as a part of a U. S.-sponsored disarmament program.

• An unconfirmed report claims that a Thor IRBM launching met with failure at a recent test in Florida. No casualties were reported.

• Our long range missile proving ground in Florida has been tied up by a strike of 900 range employees. The Air Force range is run by Pan American Airways with headquarters at Patrick AFB.

• Although not specifically named, static testing of the Polaris IRBM missile may be carried out at the new Lockheed Missile Systems Division's 4000-acre site. The $1-million facility will have four test areas and is located on the coastal side of a mountain about 15 miles from Santa Cruz, Calif. Construction will get under way in mid 1957.

• The new TM-61B Matador missile is now carried by a new transporter and launcher (see p. 299). Both tractor and trailer are equipped with pillow-type tires enabling the missile to get off the beaten path. The eight-wheel-drive "Teracruzer" is built by the Four Wheel Drive Auto Co. and the semi-trailer "Translauncher" by Goodyear Aircraft Corp.

• An adjunct to the ICBM weapons system may be a photo-recon missile. Such a "snooper" missile might be necessary, for example, to find out if an ICBM had hit its target. According to the Fairchild guided missile group, study programs for this type of missile are under way.

• Hawk is slated for a bomber defense missile. The 9-in-diam bird (apparently powered by a solid propellant rocket) is about 10 ft long and closely resembles Falcon. Cornell Aeronautical Laboratory is systems manager for the new weapon which was originally developed by Raytheon as Hawk I. The new missile has been fired from rocket sleds at Holloman AFB, N. Mex.

• Navy has awarded Bendix Aviation Corp. a $27 million contract for the production of Talos. Bendix will make the missiles at the Naval Industrial Reserve Ordnance Plant (Mishawaka, Ind.) which the company operates for the Navy. An offshoot of the Bumblebee program (JET PROPULSION, Feb. 1957, p. 180), Talos was developed under the technical direction of The Johns Hopkins University's Applied Physics Laboratory.

• On a recent trip to Bendix's Mishawaka plant, APL's Fletcher Paddison created quite a stir when he lost a briefcase full of papers described only as "dynamite." The briefcase vanished while Mr. Paddison was making a telephone call in the Illinois Central Railroad station in Chicago. The Federal Bureau of Investigation joined the Chicago police in a search for the missing documents, soon turned up the briefcase, presumably intact, in a garbage can.

• Temco Aircraft Corp. (Dallas) has received a $16-million contract from the Navy Bureau of Aeronautics for the development of a new guided missile weapon system. Details of the system are classified.

• The Air Force has negotiated cost-plus-fixed-fee contracts with missile-makers Martin, Convair, and Douglas which previously had been operating under letter contracts. Contracts cover design, fabrication, and testing costs of Martin's Titan ($358 million), Convair's Atlas ($145 million), and Douglas' Thor ($67.5 million).

AIRCRAFT

• Retirement of the last North American F-51 Mustang on Jan. 27 marked finis to the era of propeller-driven fighter planes. All USAF fighters are now jet propelled.

• Flown for the first time late last December, the Convair F-106A is now undergoing further flight testing at Edwards Air Force Base. Designed to operate at stratospheric altitudes and in all kinds of weather, the F-106A is the Air Force's newest jet interceptor.

• According to the Aircraft Industries Association of America, a new "water squeezer" now under development will be able to halt high speed jet planes without damage in less than 300 ft. Similar to the hydraulic arrester in use on the government's SMART high speed test track (JET PROPULSION, Oct. 1956, p. 894), the first unit is scheduled for delivery to the military in the near future.

More Money for Missiles

Government Expenditures in Millions of Dollars

	1958 (est.)	1957 (est.)	1956
TOTAL	2370	1852	1449
Research & Development	331	346	280
Procurement	2039 (2646)[1]	1506 (2300)	1169 (?)
Army			
R & D	87	109	112
Procurement	562 (425)	425 (?)	333 (?)
Navy			
R & D	168	146	95
Procurement	264 (428)	221 (352)	195 (238)
Air Force			
R & D	76	91	73
Procurement	1213 (1793)	860 (1948)	641 (700)

[1] Figures in parentheses represent new obligational authority as opposed to expenditures.

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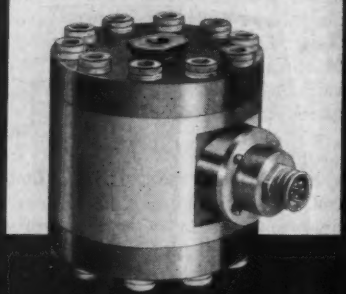

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• Among other aircraft, the Boeing B-52 (see photo) is now equipped with a new filter which removes contaminants from the air (bled from the jet engine turbocompressors) used to pressurize the cabin of the high altitude craft. The contaminants, adds filter-maker Mine Safety Appliances Co., result from decomposition of engine lubricants.

• In what was described as "a multiple-destination training mission," a flight of B-52 jet bombers recently completed a 24,325-mile, nonstop, round-the-world trip at an average speed of 525 mph. Aerial tankers refueled the planes enroute.

In the near future, B-52's will be equipped with two external fuel tanks, each with a 600-gal capacity. Pastushin Industries, Inc. (Los Angeles), has already received its first tank contract from Boeing.

COMPANIES

• Inert motor assemblies for the Sidewinder missile are being supplied by Norris-Thermador Corp. of Los Angeles. Large-scale production is under way.

• A half million dollar study contract for a new type of air-to-ground rocket was awarded Minneapolis-Honeywell Regulator Co.'s Missile Control Center at Los Angeles. The ARDC work will include design, mock-ups, and wind tunnel models. Test work will be at Eglin AFB, Fla. The rocket is to be carried by fighter aircraft.

• Production of guidance and control units for the Terrier missile will be carried out by Convair for the Navy under a $29-million contract. Production site: Pomona, Calif.

• In support of Thor IRBM development, Douglas Aircraft received $1.305 million for facilities near Nimbus, Calif. Douglas will contribute another $3 million for the 1700-acre site near Sacramento adjoining the Aerojet-General rocket motor test grounds.

• Demonstration of Rokide ceramic spray coatings for the California missile industry will be possible at Norton Co.'s Santa Clara plant. Purpose: coat test pieces, production coat small lots, and train operators.

• Plans for a 55,000 sq ft, million dollar plant in eastern Nassau County (N. Y.) were announced by Servomechanisms, Inc. The plant will house engineering and production operations of the Subsystems Group.

• Acquisition of a 2000-acre tract near Pheonix, Ariz., will provide Talco Engineering Co. with test and firing ranges for cartridge actuated devices and rockets. First slated for completion will be a rocket sled track.

• Backlog of the special computer system for the Titan ICBM has resulted in the leasing of a 20,000 sq ft plant at Anaheim, Calif. The new site will house the Scientific Instruments Div. of Beckman Instruments.

• Construction of a half million dollar engineering and laboratories building was revealed by Ryan Aeronautical Co., San Diego, Calif.

• Manufacture of Nike "elevons" will be carried on by Kellett Aircraft Corp., Horsham, Pa., for Douglas Aircraft Corp., Charlotte, N. C.

• Altec Lansing Corp., Anaheim, Calif., has started work in the field of high intensity sound. The program will include basic research and development projects, as well as test equipment suited to the noise problems faced by aircraft and missile industries.

• To increase its organizational and operational efficiency, Sperry Gyroscope Co. (Great Neck, N. Y.) has split off two new divisions, Air Armament and Surface Armament.

FOREIGN

England: Britain's guided weapons industry is on tenterhooks at present to know what the effect will be on it of talks that new Defence Minister Sandys had with his American opposite number, Mr. Wilson, and with Pentagon service experts during his visit that ended on February 2.

It has been widely rumored in Britain, on the basis of information from American sources, that he would be offered Nike and Talos for the defence of Britain. British firms fear that this might put many of their own factories out of business, especially if the offer were coupled with others of American fighters.

There has also been talk of Britain getting Thor and shorter range weapons in addition to the Corporal. In no case would such an arrangement put men out of work because Britain has no comparable projects in a production stage. A good deal of work has gone into the development of longer range missiles, however, and British workers would hope that there, as in the surface-to-air and air-to-air fields, they might have something to contribute in return for U. S. help.

• First test of the British Skylark rocket is to be made at the Woomera test range in Australia. Power for the Bristol vehicle is a Raven solid propellant rocket motor delivering 11,500 lb for 30 sec. The motor case and nozzle is 16 ft 10 in. long and has a diameter of

17 in. The 25-ft-long Skylark is expected to reach an altitude of 70 miles with an eventual try for 120 miles.

• Spaghetti-type construction is employed in the Royal Aircraft Establishment (Wescott, England) rocket motor delivering 50,000-lb thrust. Propellants are kerosene and lox. Motor is fabricated of 32 welded, hollow, stainless steel sections. The kerosene serves as coolant.

France: Rocket-powered Trident-2 aircraft has hit a speed of 1242 mph in tests over France. The three-barrel rocket engine, plus two turbojets on the wingtips, give the plane a design capability of about Mach 2. The French craft has already reached an altitude of 59,000 ft.

• After a successful 25-min flight on December 26, the Leduc ramjet 022 is getting set for new tests aimed at hitting a speed of 2485 mph. The 022 tips the scale at 13,200 lb (about 1/3 fuel). Length is 56 ft; over-all height is 15 ft. The ramjet powerplant is 39 ft long and has a diameter of about 6 ft. Sea level thrust of the ramjet is estimated at about 132,000 lb.

Italy: Airone solid propellant rocket will be used by the Japanese Air Force to arm its F-86F interceptors. The rocket has a range of about 6500 ft and is made by the Italian firm of Polverifici Stachini, Rome.

• Another Italian rocket, a prototype of a ground-to-air missile, is being tested on Sardinia. Called the AR-15, the liquid propellant (auto-feed) rocket is being developed by Whithead-Motofides, Leghorn.

• Development of an air-to-air, infrared guided missile is being undertaken by Centro Italio per la Propulsione a Reazione, Turin, under USAF contract.

Russia: Designation for a Soviet undersea, sub-launched missile is Comet I. Range of the solid propellant rocket is 50–70 miles. Also under development is an improved model with a range of 500–750 miles.

• Regular firings of an 800–1000 mile range Russian IRBM have been reported. Shots at the rate of several per month have been taking place in Siberia and the Ukraine.

• Two missiles, believed to be of Soviet origin, were publicly displayed at an astronautical exhibit in Poland. One was a large, single-stage solid propellant rocket 20–25 ft long with a diameter of 15–20 in. Another was a two-stage combination, said to be capable of reaching Mach 4. The first stage uses a cluster of three rockets of 4–6 in. diam and 6–8 ft long. The second stage consists of one highly streamlined unit of 8–12 in. diam and about 6–8 ft long.

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*Our professional prognosticators have a record to be proud of — development of Republic's famous Thundercraft, latest of which is the incredible F-105 Thunderchief, supersonic USAF fighter-bomber, capable of carrying atomic loads.

• Existence of a Soviet 85-mm rocket was revealed in Egypt. Among a large shipment of arms, the British found this antitank rocket gun. The recoilless weapon is spin-stabilized and launched from a portable barrel.

RESEARCH AND DEVELOPMENT

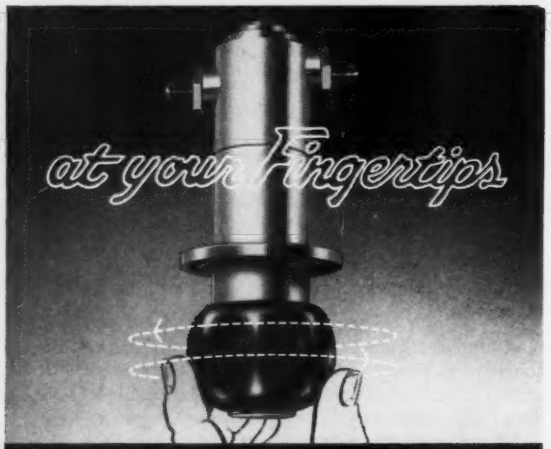
• New uses for heat have recently been mentioned. Radiating the heat generated by speeding aircraft will reduce temperatures from 6000 F to a skin temperature of 800 F. Flying at Mach 8, future aircraft will glow a brilliant red, say North American Aviation engineers. Radiation cooling was claimed to be better than any man-made cooling system. The Army has harnessed heat to come up with a novel photographic system. In the process, an aluminum plate is coated with a vinyl plastic. The coated plate is placed under a negative and exposed to a strong ultraviolet source (such as a mercury arc light) for 5 sec. An invisible image is burned into the plastic. The exposed print is then baked for 5 min at 320–350 F to produce a finished print. The process was discovered by Ferro Chemical Corp., and development work was carried out by the Signal Corps Engineering Laboratory at Fort Monmouth, N. J. The process is unaffected by gamma radiation, and does not need a darkroom, chemicals, or water supply.

• A guidance system developed by Minneapolis-Honeywell is claimed to be foolproof and detectionproof. Tagged the "siderial equatorial mount," the unit (see photo) will use the stationary North Star as a reference point in keeping missile and rockets on target.

• To speed research on the Thor IRBM, Douglas Aircraft has ordered a 200-channel transistorized data-processing system from Beckman Instruments, Inc. Douglas will use the equipment to monitor up to 200 individual thermocouples and strain gages attached to missile parts under tests.

• At a recent meeting of the Steamship Historical Society of America, Maritime Administrator Clarence G. Morse peered into the twenty-first century, saw there fleets of nuclear-powered jet submarine freighters and tankers operating, by remote control, at speeds of 50 to 60 knots.

• Republic Aviation Corp. recently signed a design contract with Burns and Roe, Inc., for a new million dollar wind tunnel facility (see sketch). The facility will consist of one transonic tunnel, one supersonic (Mach 4) tunnel, and two tunnels of the intermittent blowdown type.



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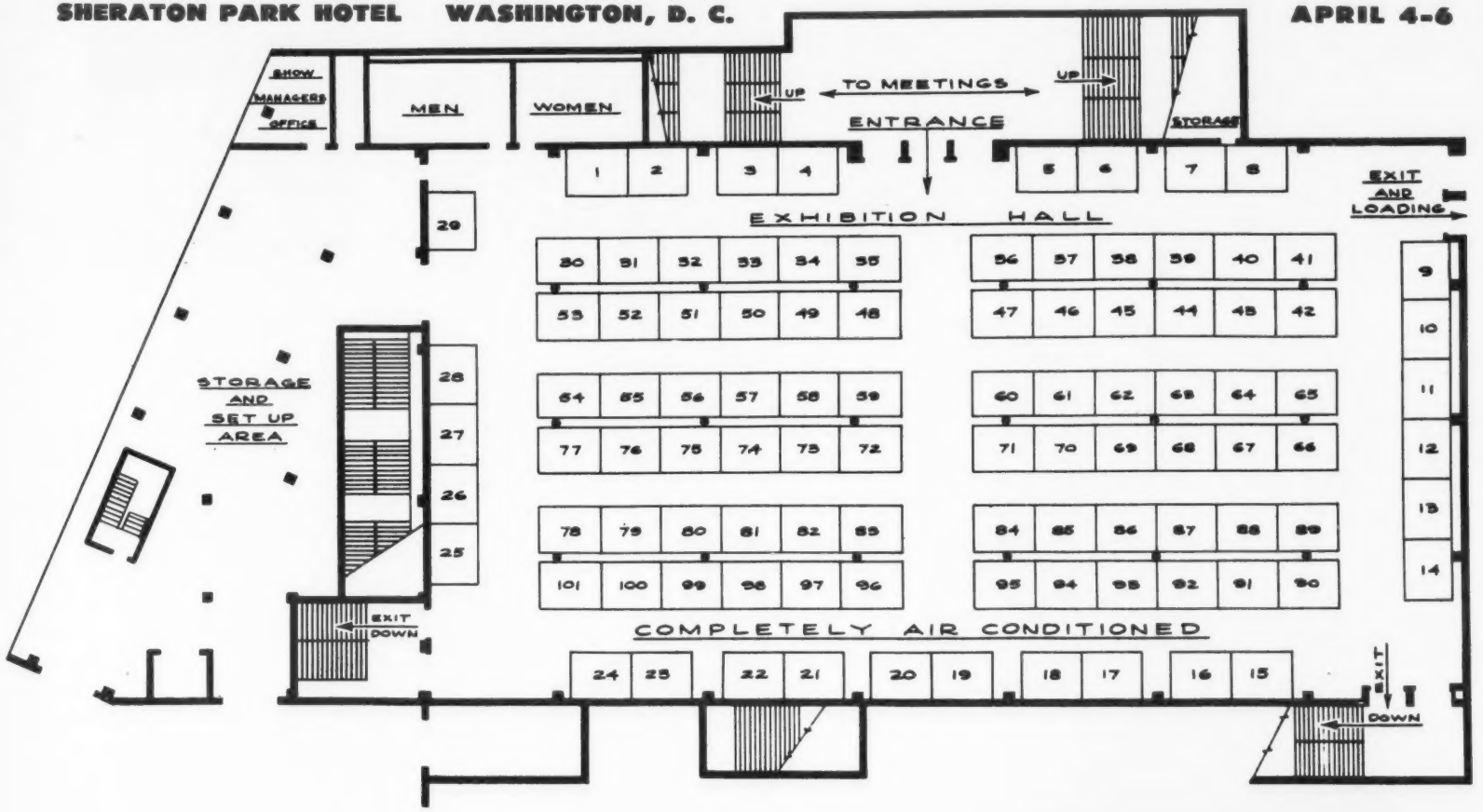

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In trying to beat the problem, scientists have come up with a new approach to an old technique. It's called *flame spraying*. Here, briefly, is what it is and what it does:

FLAME spraying is, essentially, a new surface coating technique. The treatment of surfaces to protect them against high temperature, corrosion, or wear, of course, is not new. Such techniques as case hardening or, more familiar, porcelainizing have been well known for a century or more.

For ordinary conditions, these standard surface treatment methods have proved more than adequate. But they have not stood up under the environmental extremes of temperature and corrosion found in the interior of a rocket motor or jet engine. Nor have metallurgists yet developed metals or alloys that unprotected can withstand the external environmental extremes that hypersonic vehicles are now beginning to encounter. Consequently, new protective techniques have had to be developed.

A Second Look: Among the most promising of the "new" techniques are flame spraying and porcelainizing. Porcelainizing as such, of course, is a fairly old process. But work currently under way at such places as the Bureau of Standards and Solar Aircraft, aimed at making procelainizing suitable for jet and rocket applications has already resulted in definite improvements over conventional porcelainizing methods. And so, some coatings men believe, porcelainizing may yet prove significant in the protection of missile parts against corrosion and high temperature.

But it is flame spraying that has received the most attention from the trade. Considerably more recent a discovery than porcelainizing, it is not, however, a new process. It was first investigated in the early 1900's. Although it showed promise, there was no immediate need for flame spraying. Established coating methods satisfied all existing requirements and were much less expensive. So flame spraying was set aside until the advent of jets and rockets. Then, 50 years later, scientists took a second look at the process.

What Is It? In general, flame spraying consists of those techniques which use a gas-oxygen flame to heat materials—either in wire or powder form—as (or immediately before) they are projected upon the surface to be coated.

The coating materials themselves range from plastics, through metals and alloys, up to and including refractory oxides. The composition and form of the coating material generally determine which flame spraying method will be used.

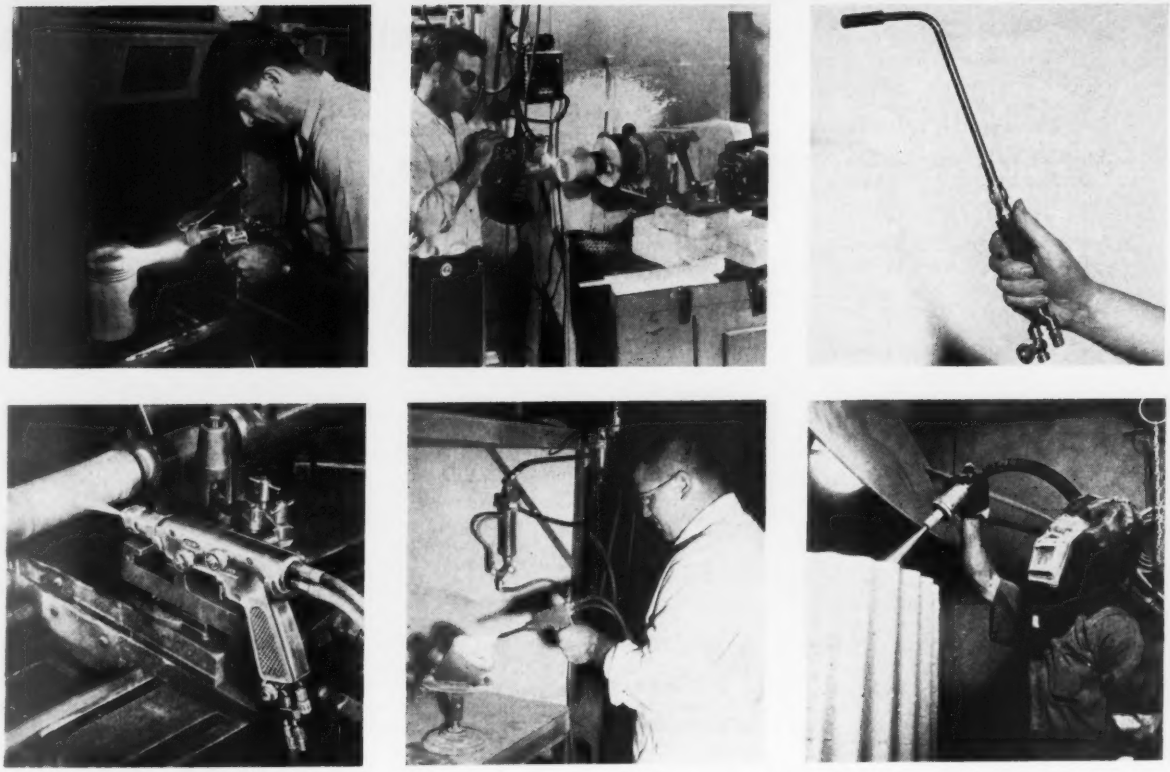
Careful surface preparation is required in all flame spraying methods to insure adherence of the coating. Sand or grit blasting is the preferred preparation because it produces jagged irregularities on which the coating readily "keys" to form a good mechanical bond. Other methods such as grinding, acid etching, etc., produce less pronounced surface irregularities, and the keying of the interfacial connection between base material and coating is less effective.

Good mechanical bonding is a prerequisite, even when remelting is later employed to produce a metallurgical bond, because of the rather severe thermal shock involved in remelting.

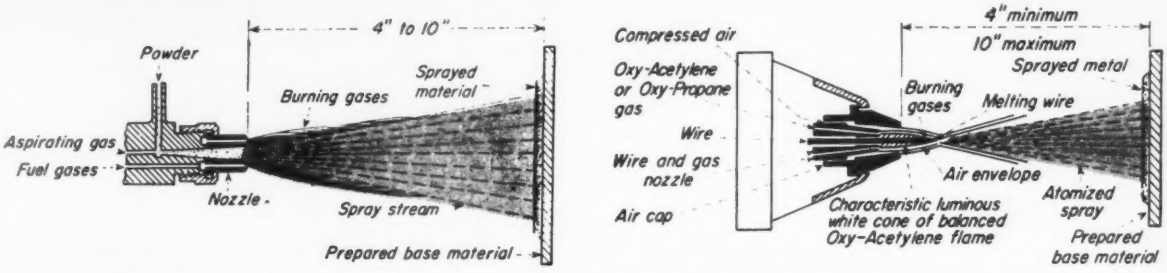
Powder or Wire? Flame spraying methods can be divided into two major categories: those using powdered coating materials and those using wire or sintered rod forms.

In powder spraying, the coating particles are carried through the flame by a conveying gas such as air or nitrogen or, in some cases, by the fuel gases themselves. In flame spraying with wires, the coating material—in the form of a wire or rod—feeds into the flame at a rate equal to or slightly less than its melting rate. In both methods, the

Using 5500 F oxy-acetylene flame, Ryan ceramicist flame sprays stainless steel part with powdered cermets to prolong high-temperature operating life.



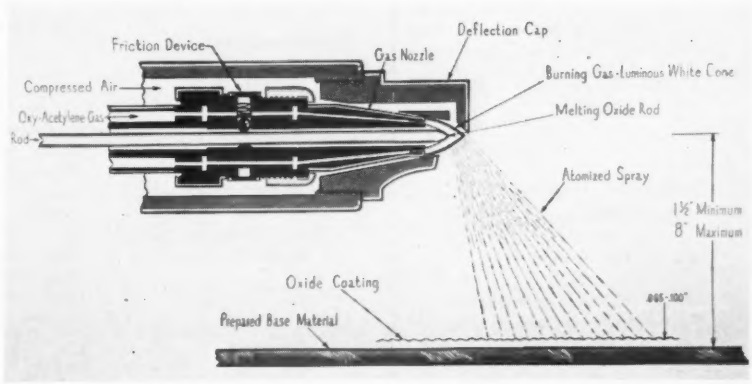
FRAME SPRAYING ARSENAL: This is a cross section of the many different guns used in various flame spraying processes . . . . .



. . . but all instruments are of three basic types: powder-fed (left), wire-fed (right), or rod-fed (below).

molten material is projected onto the work surface usually by a stream of compressed air. For this reason, improper operation is apparent immediately in the wire-fed method, and it is, perhaps, somewhat easier to determine optimum coating conditions.

Too, the wire method offers better control over process parameters because the feed-melting rate of the coating material is more readily controllable. In powder spraying, however, the temperature attained by each individual particle depends upon particle size, flame temperature, and residence time of the particle in the flame. Residence time, in turn, depends upon particle velocity and flame length. And because these parameters are mutually interdependent, control of particle temperature (and coating conditions) is possible only within a rather limited range.



On the other hand, powder spraying is capable of higher deposition rates because of better heat transfer resulting from more intimate contact between flame and coating material. And, presently at least, powder spraying appears to be the more popular method.

Coating Choice: The selection of a particular type of coating will, of course, depend upon the job to be

Some Promising Flam

Company	Process	Composition	Substrate	Thickness	Temperature Limitation (F)	Adherence
American Agile Corp. (Bedford, Ohio)	Agilene, Agilide, Agilux	polyethylene; P.V.C.	——	0.0625″	175	——
Armour Research Foundation (Chicago, Ill.	Flame Alumina A	99% aluminum oxide	——	0.001–0.100″	3650 (mp)	excellent
	Flame Alumina D	97% aluminum oxide	——	0.001–0.040″	3650 (mp)	excellent
	Flame Zirconia	98% zirconium oxide	——	0.001–0.015″	4750 (mp)	excellent
	Flame Ceramic IA	iron-aluminum-titanium	——	0.001–0.100″	>2500	excellent
Continental Coatings Corp. (Chicago, Ill.)	Flame Ceramics	98.6% aluminum oxide stabilized 98% zirconium oxide	magnesium, aluminum, steel, glass	0.0625″ & up	3500 (mp)	good
		titania		0.005–0.050″	4500	good
		cermets		——	3270 (mp)	——
				——	——	excellent
Linde Air Products Co., A Div. of Union Carbide & Carbon Corp. (New York)	Flame-Plating	92% tungsten carbide–8% cobalt	steels, cast iron, aluminum, titanium, magnesium, molybdenum copper, brass, bronze, and their alloys	0.002–0.010″	——	——
		99% aluminum oxide		0.001–0.040″	1800	——
	——	polyethylene	——	——	——	——
Metallizing Engineering Co., Inc. (Westbury, N. Y.)	ThermoSpray	alumina	metals, glass, plastics, ceramics, cloth, paper	0.005–0.025″	3700 (mp)	——
		zirconia		0.005–0.025″	4600 (mp)	——
		boron-silicon alloys; stainless steels; chrome-nickel alloys; bronze; ceramics; copper; lead; tin; zinc; aluminum	——	——	——	——
Metalweld, Inc. (Philadelphia, Pa.)	Metallizing	aluminum	steel	0.125″ & up	——	excellent
		Nichrome	iron, steel	0.125″	1800	excellent
		Nichrome & aluminum	steel	——	1800 & above	——
		zinc; aluminum	iron, steel	0.008–0.01″	——	——
		nickel	iron, steel	——	——	——
		tin	iron, copper, steel, brass-metal bearings	——	——	——
		Stainless Steels #304 or 420	iron ——	——	——	——
Montaine Corp. (Chicago, Ill.)	Flame Rock Ceramics	97% Al_2O_3 (B-2)	——	0.005″	3500	good
Norton Co. (Worcester, Mass.)	Rokide A	98.6% aluminum oxide	iron, steel, nickel-based alloys, copper, aluminum, brass, molybdenum, graphite-carbon, ceramics, glass, zinc, magnesium, some plastics, lead, solder, Fiberglas, asbestos, titanium	0.005–0.050″	3600 (mp)	excellent
	Rokide Z	98% zirconium oxide		0.005–0.050″	4500 (mp)	excellent
	Rokide ZS	65% zirconium oxide and 34% silica		0.005–0.050″	3000	good
Ryan Aeronautical Co. (San Diego, Calif.)	——	nickel-magnesia	stainless; Inconel	0.001–0.020″	3500	——
Wall Colmonoy Corp. (Detroit, Mich.)	Sprayweld	chromium-boron-nickel mixtures	mild & low alloy steels, higher carbon & stainless if heat treated	0.010–0.060″	1900–2225	excellent after fusing

[1] All data were supplied by companies.

Spraying Processes[1]

Porosity	Hardness	Abrasion Resistance	Impact Resistance	Thermal Shock Resistance	Corrosion Resistance	Flexibility	Applications
—	—	—	—	—	very good	—	storage tanks for chemical propellants such as ammonia, aniline, hydrogen peroxide, nitric acid
8–15%	5–7 (Moh)	very good	excellent	good	excellent	excellent	electrical insulation, rocket nozzles, bearing surfaces, chemical storage tanks, abrasion & impact protection, friction surfaces
8–15%	6–7 (Moh)	very good	good	good	poor to acids	very good	
8–20%	low	fair	excellent	excellent	excellent	excellent	high temperature impact protection, coating for carbon
slight	7–8 (Moh)	excellent	excellent	good	poor to boiling acid	fair	pump housing protection, hard surface for aluminum, wear & corrosion protection
slight above 7 mils	1600 (Vickers)	very good	good	good	very good	—	rocket nozzles, turbine plates, electrical components, heating elements, thermal sensing units
8–12%	8 (Moh)	excellent	excellent	excellent	very good	excellent	rocket nozzles, burners, flame ducts, combustion chambers
0%	—	excellent	excellent	excellent	excellent	—	—
0 to slight	7–8 (Moh)	excellent	excellent	good	poor to boiling acid	fair	protection against wear & corrosion—pump housings, inlet air ducts, etc.
0.5%	1350 (Vickers)	excellent	fair	excellent	poor to most acids and some alkalis	low modulus of elasticity	aircraft turbine engine seals, cold forming dies, ball piston pump bushings, aluminum rocker arms
<1%	1200 (Vickers)	excellent	—	—	—	—	—
—	—	—	—	—	—	—	—
6–10%	9 (Moh)	—	—	good	—	—	—
6–10%	8 (Moh)	—	—	good	—	—	thermocouple tube, pump parts, electronic components, insulators, ignitors
—	—	—	—	—	—	—	—
0 to slight	—	excellent	—	—	—	—	protection against heat corrosion where sulfur gases are present
0 to slight	—	excellent	—	—	—	—	protection against heat corrosion where sulfur gases are not present
—	—	excellent	—	—	—	—	protection against heat oxidation where sulfur gases are present
porous	—	—	—	—	—	—	cathodic protection
porous	—	—	—	—	—	—	protection against contamination
porous	—	—	—	—	—	—	protection against contamination
porous	—	—	—	—	—	—	protection against contamination electrical insulation, protection against molten metals hard facing
low	9 (Moh)	—	—	—	high	—	
8–12%	very good	very good	—	good	very good	—	rocket—nozzles, motor tube linings, thermal barviews; guided missile—vanes, skin protection, motor components; ramjet—tailpipe lining; gas turbine—inner combustion chamber lining, cross fire tube lining, flap nozzle coating, housing and shroud ring insulation; burner parts protection
8–12%	good	good	—	very good	very good	—	
8–12%	good	good	—	good	very good	—	
—	—	—	—	—	—	—	afterburner liners, combustion chambers, transition liners, exhaust systems
none after fusing	56–61, 45–50, 35–40, 15–20 (Rockwell C)	fair to excellent	good to very good	—	excellent	—	bearing surfaces, forming dies, exhaust valves

done and, in turn, may determine the choice of the flame spraying method. Here, briefly, is a review of the basic flame spraying processes and their applications (for greater detail, see table: Some Promising Flame Spraying Processes):

Powder-Fed Processes

Powder-fed processes are basically similar in that the powdered material is fed from a device which mixes the individual particles of powder with a stream of conveying gas. The combustion systems are also similar in that a fuel gas-oxygen mixture is the means of supplying heat.

For purposes of illustration the powder process can be divided into three major categories: plastics, metals and refractory materials.

Plastics: American Agile Co. manufactures a plastic spraying gun, powder dispenser and associated hose and gas control equipment. The spraying device uses a single flame to heat the particles of powdered coating material which are conveyed in a stream of air from the powder dispensing device. Control of particle temperature is achieved by varying the air-acetylene ratio: A long, fuel rich, low temperature flame is used for the actual spraying process and a shorter, more nearly stoichiometric flame for pre-heating of the surface prior to spraying.

The powder used in the Agile process is essentially polyethylene; the properties of the coating are said to be equal in their chemical and physical characteristics to monolithic polyethylene. Recommended procedure for producing coatings with the Agile process involves first a sand-blasting technique for surface preparation; second, pre-heating of the surface to be sprayed; and, finally, the spraying operation with a fuel-rich flame.

Linde Air Products Co. also produces a plastic spraying device. It is somewhat similar to the American Agile equipment except that instead of using a single flame through which the powdered material is conveyed, it uses a ring of flames. The powdered material is carried in a separate stream of gas which issues from a centrally located orifice within the ring.

With this arrangement, heating of the particles is accomplished by proximity to the surrounding regions of secondary combustion rather than by both primary and secondary combustion as in the case of the American Agile process. To prevent overheating of the powder a concentric air jet issues from an annular opening between the circle of heating flames and the central powder opening. Air supplied to the cooling jet also serves to cool the nozzle of the spray gun. This is necessary since the heating flames are rooted closely to the flame ports in the nozzle. Pre-heating of the surface is also recommended in the Linde process.

In both processes, fusion and coalescence of the particles into a continuous film occurs on the surface during spraying. Among the advantages listed for these processes: comparatively simple equipment and technique requirements, economy of operation, low cost of raw materials.

According to the manufacturers, these processes are capable of producing smooth, impervious polyethylene coatings ranging in thickness up to about $^1/_8$ in. on almost any metal surface. Such coatings are effective in preventing serious attack on metals by corrosive chemicals such as acids, strong bases, various propellants, etc.

Metals: The Wall-Colmonoy process uses a spray gun identical in principle to the Linde polyethylene spray gun; i.e., the powdered materials are carried to the gun by a stream of air or inert gas which is separate from the fuel and oxidant gases supplying the flame. In this process the particles are heated by the secondary combustion region of the heating flames, no contact with the primary cones taking place.

The powder feeding device used in the Wall-Colmonoy process depends for its operation upon suction created by the passage of cooling air through a venturi in the gun. Thus the cooling air flow is not determined solely by the necessary cooling for the spray nozzle but must also be sufficient to create suction for the operation of the powder feeder.

The Metallizing Engineering Co. in its ThermoSpray process uses an entirely different method of supplying powdered metals or oxides to the heating flame. The powder is fed by gravity and suction directly from a hopper mounted on the gun into a venturi which is connected to the passage carrying the combustible gas mixture. Suction created by the passage of gas through the venturi aids in feeding powdered material.

This device heats the particles by direct contact with both the primary and secondary combustion regions of the heating flame. Stability of the centrally located spraying flame is insured by a ring of smaller, surrounding flames utilizing the same combustible gas mixture. The manufacturer claims that this principle of operation results in higher deposition efficiency than can be achieved by the use of less direct methods of heating the powdered coating material.

Metallic flame-sprayed coatings find application in the building up of worn machine parts, in hard facing to provide wear and erosion resistant surfaces and in protection of metal surfaces against corrosion and chemical attack at both high and low temperature.

Refractory materials: The advantages of using refractory oxides to produce coatings for metallic surfaces can readily be visualized since certain of these materials have melting points in the region of 4500 F and also possess a low thermal conductivity.

In the past it has been thought that the brittle, low strength properties of such materials would preclude the possibility of their use as coatings for metals. Later developments have shown, however, that flame spraying techniques can be used to soften or melt the local surface region of powdered refractory materials. Under these conditions, individual particles bond or sinter together to form a continuous "closely woven web or fabric" of refractory material which possesses greater flexibility than would be characteristic of a monolithic structure of the material. For this reason flame-sprayed refractory oxide coatings are capable of withstanding a degree of thermal shock which would not be anticipated by a study of the monolithic structure.

Porosity exists in such coatings to an extent that permits slow penetration of the coating by air; thus such coatings do not offer protection against high temperature corrosion for long periods of time. However, refractory oxide coatings are effective as thermal barriers by reason of their low thermal conductivity.

Metallizing Engineering Co.'s ThermoSpray process previously described can be used to apply the coating of refractory materials and is effective in such an application by virtue of efficient particle heating.

Montaine Corp. produces Flame Rock Ceramics in a process using a flame spraying device similar to the Wall-Colmonoy apparatus in which the powdered coating material is carried in a stream of conveying gas and heated by the secondary region of a ring of flames. This process uses finely powdered refractory materials which can be softened in the secondary flame region, thus producing a continuous well-bonded coating.

Ryan Aeronautical Co. uses a Wall-Colmonoy type process. But the Ryan process uses powdered nickel and powdered magnesium oxide which is first sintered and then reground. This powder produces a coating of combined refractory oxide and metal usually called "Cermet." It is characterized by a strong metallurgical bond with the base material, resistance to thermal shock, and ability to protect the base metal from oxygen attack at high temperature.

Linde Air Products Co. has developed a unique process called Flame Plating. Powdered coating material, suspended in an explosive mixture of oxygen and acetylene, is ignited in a detonation chamber. Ignition is initiated at about

$^1/_{10}$ sec intervals by means of an electric spark. The resulting detonation heats the particles and ejects them from the exhaust tube at a high velocity.

The coating material primarily used with this process is a hard surface alloy of cobalt and tungsten carbide. While complete details on the Linde Flame Plating process are not available, the process appears to have the advantage of control over particle temperature and velocity. Thus it is capable of producing a well-bonded, impervious coating without the necessity for post heating.

Wire- and Rod-Fed Processes

Coating materials falling under this category generally find the same applications as powdered metals and ceramics. But instead of feeding into the flame as individual particles, the material is pre-formed into a wire or rod which is slowly drawn or propelled into the flame at a speed approximately equal to its melting rate.

Metals: The metallizing process is an old one and involves the spraying of atomized molten metal which has been melted by the use of flames upon a continuously fed wire. The Metallizing Engineering Co. manufactures a wire-fed metallizing gun in which the wire is propelled into the flame by a turbine device powered by the same gas which propels the atomized metal on to the work surface. A similar device is also manufactured by the Mogul-Metallizing Co. of America.

Ceramics: The Norton Co. has developed a unique flame spraying process for producing high temperature, refractory Rokide coatings. This process utilizes a metallizing or wire-fed device which propels a sintered rod of refractory material into the flame region. This process is characterized by the close control of spraying conditions. The refractory material is held in the flame region until melting takes place; thus only molten particles are propelled onto the surface, and a continuous coating is thereby produced.

No Limit: In converting heat energy into work, jet and rocket engines depend upon extreme temperature differentials. To the metallurgist, they offer a tremendous challenge for materials which can withstand ever-increasing temperatures, corrosion conditions, vibration and thermal shock, etc.

Many times during the past decade metallurgists have successfully met this challenge. But now they are beginning to question the ability of unprotected metals to withstand temperatures above 2000 F. Meanwhile, the range of proposed applications in the jet propulsion field is already pushing toward the 3000 F mark.

The answer then, many metallurgists believe, lies in the protection of the vital metal components with coatings which can act as thermal barriers, corrosion barriers, etc. And flame-sprayed coatings—albeit only one approach to the problem—show a great deal of promise.

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Correction

In the Careers Supplement to JET PROPULSION in February, the wrong photograph was inadvertently inserted in the story describing employment opportunities at Reaction Motors, Inc. Photo below shows the Viking rocket described in the Reaction Motors article.

Navy Viking high altitude research rocket powered by an RMI 20,000-lb-thrust engine leaves launching platform.

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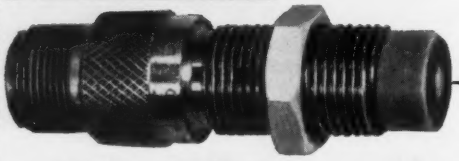

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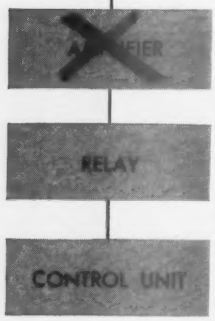

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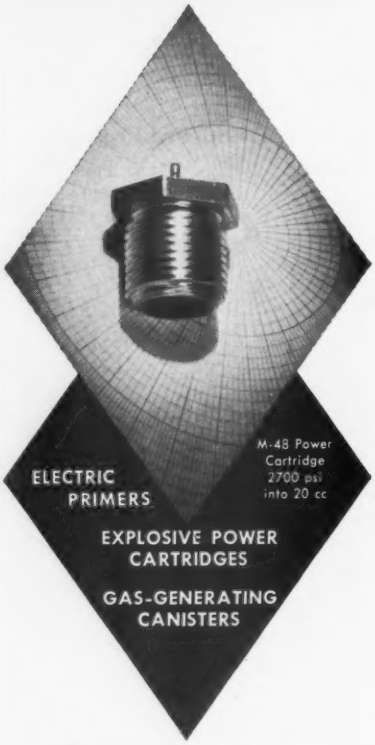

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Space Flight Notes

JOHN GUSTAVSON, Convair-Astronautics, *Contributor*

Soviet Astronautics

"MANKIND will not stay on the Earth forever, but, in the pursuit of the world and space, will at first timidly penetrate beyond the limits of the atmosphere and then will conquer all the space around the sun."

K. E. TSIOLKOVSKII (1913)

These lines are taken, together with other quotations in this note, from a Rand Research Memorandum recently published under the title, "A Casebook on Soviet Astronautics," (RM-1760) prepared by F. J. Krieger.

While military considerations prevent the engineers and scientists of the West from studying and evaluating the Russian progress in missile engineering, we still have an opportunity to form an impression of their application of this science to a peaceful purpose—space flight.

The Pioneers

Konstantin Eduardovich Tsiolkovskii is among the fathers of space flight. The Russian scientist was born in a little village near Moscow in 1857. He became a teacher, and developed a keen interest for physics. He was especially interested in airships and made contributions of a theoretical nature to early aeronautics long before the time of the Wright brothers' first flight in this country. Deafness prevented him from making a career at a university, but, in its perverted way, allowed him precious time to focus attention on the works of contemporary scientists. Although Tsiolkovskii worked under the handicap of rural isolation, living far from the center of science, St. Petersburg (now Leningrad), his genius has been unquestionably proved through examples of his calculations.

Toward the end of the century Tsiolkovskii began to show special interest in space flight, and in 1895 he mentions for the first time, in a popular magazine to which he had submitted articles, the possibility of space flight. The speculations of this small-town scientist were not taken seriously, however, and his paper on the principles of rocket flight, submitted in 1898, was not published until 1903. From 1911 until his retirement, he had articles on rockets and space flight published regularly; and in 1924, when Robert Goddard and Hermann Oberth had created active interest and encouraged contributions to astronautics with their published works on space flight, the Russians re-discovered Tsiolkovskii and proclaimed him the father of space flight. His paper had been ignored for two decades. No doubt Tsiolkovskii deserves this title, and the Russians have certainly made up for their former lack of interest by crediting his endeavor, honoring him, and consulting him until his death in 1935.

Among Tsiolkovskii's contributions we find treatises on the necessity of using liquid fuels, on step principles, and sketches of space ships (Fig. 1).

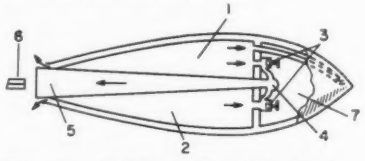


Fig. 1. Tsiolkovskii's interplanetary rocket ship—1 and 2 are propellant tanks; 3 symbolizes pumps; 4 is the combustion chamber, 5 the nozzle, and 6 the exhaust deflection vanes. The passenger cabin is in the front of the ship, 7.

Also included among the Russian pioneers is F. A. Tsander, an engineer who dedicated a major part of his life to the evaluation of reactive engines and space vehicles. Tsander began his career as an amateur astronomer, turning his interest gradually toward advanced study of reaction motors as early as 1908 at a major Russian university. In 1920 he presented a paper at the Moscow Province Conference of Inventors; here the paper caught the attention of Lenin who was sufficiently impressed to render Tsander his support.

Tsander proposed in 1924 to utilize metallic parts of the early stages of the space vehicle, such as airfoils and control surfaces, for burning in the rocket engine, when useless after leaving the atmosphere.

Over the period from 1928 to 1932 an astronautical encyclopedia was published in the Soviet Union. There is very little information available pertaining to the author of the text, a professor Nikolai Alekseevich Rynin of the University of Leningrad. It is known, however, that he was co-founder of Lengird, the Leningrad section of Gruppa Izucheniya Reaktivnogo Dvizheniya, the pre-war Russian rocket society.

Rynin's encyclopedia is mainly historical and bibliographical and cannot be regarded as an important contribution to astronautics. The scope of this work is revealed through the titles of the nine volumes which are:

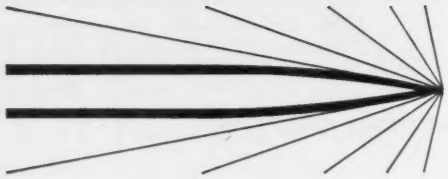
I. Dreams, Legends, and First Fantasies (1928)
II. Cosmic Ships: Interplanetary Communications[1] in the Fantasies of Novelists (1928)
III. Radiant Energy in the Fantasies of the Novelists and in Projects of Scientists (1931)
IV. Rockets and Direct Reaction Motors: History, Theory, and Technology (1929)
V. Theory of Reactive Motion (1929)
VI. Superaviation and Superartillery (1929)
VII. Russian Inventor and Scientist Konstantin Eduardovich Tsiolkovskii: His Biography, Works, and Rockets (1931)
VIII. Theory of Cosmic Flight (1932)
IX. Astronavigation: Chronicle and Biography (1932)

Rocket Development

The cumulative efforts of these men, together with other able scientists and engineers, marked a turning point in the vast field of astronautics. During the thirties the Russian rocket societies developed artillery rockets which aided them in fighting the German forces in World War II. At the end of the war, the Russians took possession of the factories which had produced the V-2 rockets, as well as rocket facilities in Eastern Germany, such as the famous Peenemuende center. More than 200 German rocket scientists were brought to Russia to perform specific functions behind the Iron Curtain. In this manner, the Soviet Union produced several thousand V-2 rockets, and must have gained much experience in missile production and fundamental rocket and upper atmosphere research.

As a result, they have improved the V-2 engine and developed an engine capable of delivering 250,000-lb thrust at a chamber pressure of 900 psi. This is not the work of the captured German

[1] The Russian term "interplanetary communication" is synonymous with "interplanetary flight."



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scientists, as they were not integrated in any Russian developmental project; during 1950 to 1951, all of the "borrowed" rocket engineers were released and returned to Germany. The Russians have their own specialists: Semenov, Zel'dovich, Kristianovich, and Sedov, capable men in the fields of combustion and aerodynamics.

The Russian developments in areas of nuclear physics, aviation, telemechanics, and automatics, with due regard for the known accomplishments, some of which are listed above, show clearly that the Soviet Union has made progress and has established potential in the study for the advancement of space flight.

Astronautics in the Soviet Press

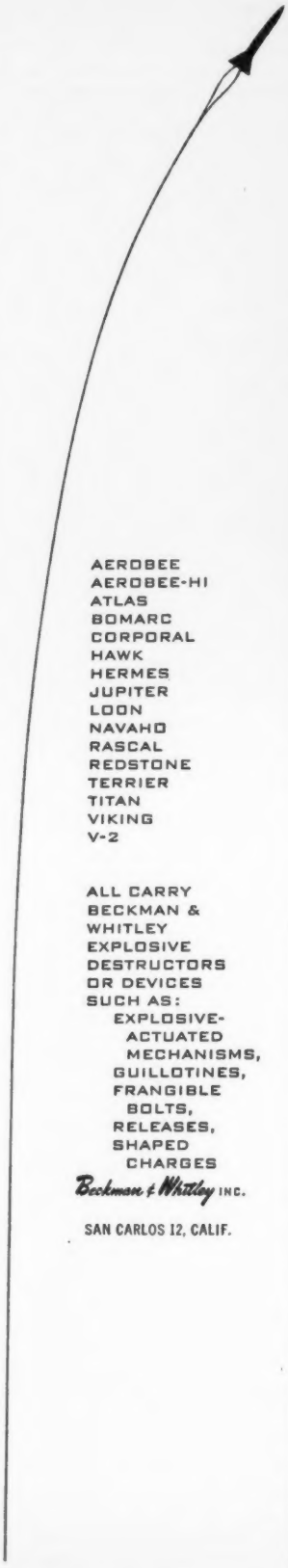
During the last few years a noticeable change has taken place in the policy of the Soviet Press. Formerly, all releases pertaining to space flight followed an established pattern. The article would begin with uninhibited praise of the Russian pioneers, especially of Tsiolkovskii; then it would describe activity being carried on at the present (always an American experiment, including exact data, though no mention was made of the West), and finally, the article would present a glorified future where Russian space ships conquered the planets. These articles, even when technical, would also conclude with a final touch of political propaganda. Following is an excerpt translated from a popular technical magazine, *Znanie-Sila*, April 1950:

"The reactionary science serving Anglo-American imperialism sets forth entirely different goals for interplanetary travels. It is not the study of the nature of surrounding worlds in the interest of science, but the search for strategic raw materials for a new war. It is not a research laboratory for the study of interplanetary spaces, but yet another extraterrestrial base for attacking the Soviet Union and the countries of the People's Democracy. American imperialists, who are possessed by a mania of world domination, are threatening the entire universe and are making extravagant plans for transforming the entire solar system into an American colony.

Tsiolkovskii warned against this more than 20 years ago. He wrote: 'Many visualize celestial ships with people traveling from planet to planet, the gradual population of the planets and the extraction therefrom of profits which ordinary terrestrial colonies yield. The fact will be far different from this.'

Not long before his death, the founder of space flight, Konstantin Eduardovich Tsiolkovskii, wrote a letter to the People's Leader, Comrade Stalin, in which he bequeathed all his works to the Soviet people and to the party of the Bolsheviks—the true bearers of progress. These works came into reliable hands.

The insane plans of the imperialists are doomed to failure. The science of our



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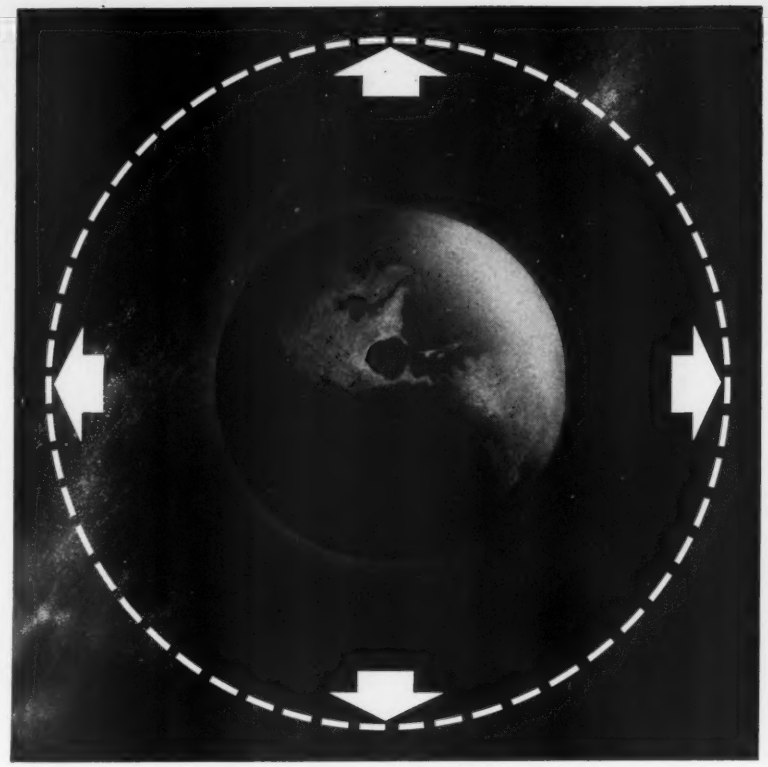

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country, having spoken the first word on interplanetary flights, will also be the first to realize this long-cherished dream of mankind."

Recently, the tone has changed. Technical articles of high quality treating original projects have been found in the Russian press, particularly after the United States' presidential announcement of July 29, 1955, when the IGY Satellite Program was officially initiated. Russian scientists also attended the Sixth Congress of the International Astronautical Federation in Copenhagen, August 1955. Sedov, famous aerodynamicist, and Ogorodnikov, astronomer, were official observers. At the 1956 Congress in Rome, Soviet Russia was accepted as a member of the Federation. The most prominent Russian society for space travel is the Astronautics Section of the V.P. Chkalov Central Aero-club, in Moscow.

As a sample of the latest approach to the subject of space flight as it appears in Soviet journalism, the following excerpt has been taken out of context from "The Road into the Cosmic," by Yu. S. Khlebtsevich, printed in *Nauka i Zhizn'*, November 1955:

"The investigation of cosmic space, in spite of its great scientific importance, is not a goal in itself. It will serve as a preparation for the next stage in the development of interplanetary flights—the stage of studying the Moon by means of radiotelecontrolled rockets equipped with suitable apparatus.

Before setting out for the Moon, man must ascertain what he might encounter during his journey into a world completely unsuited for him. Only by knowing this will it be possible to ensure passenger safety during takeoff, flight, and landing of the cosmic ship and to guarantee the return of the courageous investigators to their native planet. At the same time, it is still necessary to completely work out the landing of the rocket on the Moon, its takeoff from the lunar surface, and its landing on the Earth. It is also necessary to check the correctness of the calculations which determine the influence of the attraction of the Sun and the other planets on the flight trajectory of the cosmic ship, and to ascertain the physical properties of the lunar atmosphere and the lunar surface, in order to take them into account in designing the rocket and implementing it with suitable equipment.

We shall recall further that the flight of a rocket to the Moon and back with a crew is possible in the contemporary state of jet technology only if the route of this flight is divided into several intermediate stages with a guarantee of refueling the rocket at each stage. The use of atomic energy facilitates the solution of this task, but then introduces a number of additional conditions connected with ensuring the safety of the crew—primarily its protection against harmful radioactive radiations.

Flight to the Moon demands, moreover, extremely high precision in maintaining the calculated trajectory and flight chart. Up to the present, almost no attention has been paid to these characteristics of cosmic flight. However, an error of only ±0.1 per cent in the value of the vector of the initial takeoff velocity of a rocket heading for the Moon will result in a 'short' or an 'over' of the order of ±12.5 per cent of the general length of path, or several tens of thousands of kilometers. Consequently, the cosmic ship will still require an additional supply of fuel for maneuvering.

Finally, the real danger of meteorites hitting the rocket both in flight and on the Moon greatly aggravates the difficulties of the original solution of all the problems of interplanetary travel involving direct participation of people.

All the above obstacles can be completely overcome in relatively short periods of time and without sacrifices, moreover, only in one case: If automatic radiotelecontrolled unmanned rockets are sent on the first flights to the Moon.

A rocket controlled by radio from the Earth will 'land' on the Moon, instead of a crew, a mobile laboratory which externally somewhat resembles a small tank

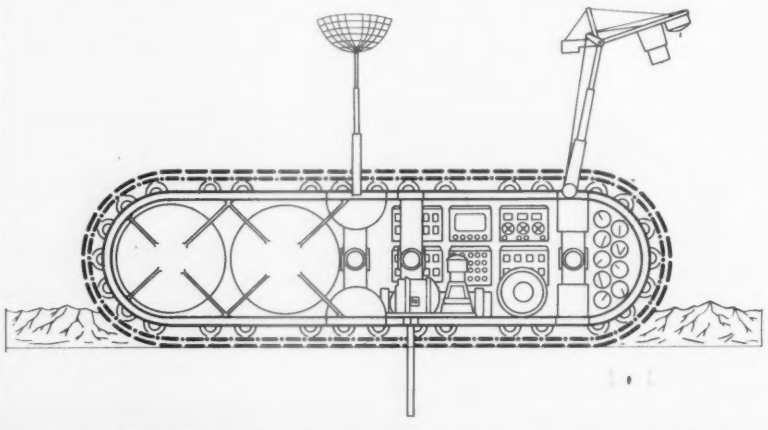


Fig. 2. Russian tankette-laboratory—proposed for preliminary investigation of the moon. Note propellants for gas generators to the left, radio antenna in the center, and TV camera boom with light projector to the right. As the tankette-lab is unmanned and radio controlled, the instruments with the expensive looking dials are probably only dead weight.

(see Fig. 2). This 'tankette-laboratory,' as we shall call it, will also be controlled by radio from the Earth. The transmitting television camera, mounted on a radio controlled boom having several degrees of freedom and fixed on the tankette-laboratory, will permit scientists on the Earth to observe the lunar surface and the lunar sky with the disk of our planet visible on it (all this can be photographed on the Earth), and to determine the safest path for the movement of the laboratory. Aboard it will be placed various automatic instruments transmitting to the Earth their readings on the state and properties of the lunar atmosphere and the lunar surface. For moving the tankette and operating its equipment, the necessary store of fuel and oxidant for the engine will be available. Utilization of other known sources of energy is also possible. Calculations show that for a tankette-laboratory with a total weight of not more than several hundred kilograms, serious initial investigations of the Moon, sufficient for carrying out the next stage—the mastery of the Moon by Man—are possible in principle; and what is more, in case of necessity, it will be possible to 'land' other tankettes, taking into account the results obtained earlier."

Russian Potential

The conclusion must therefore be that we are able to find in Russia today genuine interest in space flight, a well-developed rocket technology, and competent scientists and engineers. Moon projects have been mentioned from time to time, and Russia also claims to prepare an artificial satellite which may very well precede the Vanguard. The Russian satellite is believed to be of the same size (20 in. diam), but heavier than the Vanguard satellite (100 lb instead of 20 lb).

We must not underestimate the potential of Soviet Russia—neither politically nor astronautically.

PEnnsylvania 6-6845

The telephone number of the AMERICAN ROCKET SOCIETY (and JET PROPULSION) has been changed to PEnnsylvania 6-6845. The address is still 500 Fifth Avenue, New York 36, N. Y.

ARS Meetings Calendar

April 3–6: ARS Spring Meeting, Sheraton Park Hotel, Washington, D. C.
June 10–13: ARS Semi-Annual Meeting, Hotel St. Francis, San Francisco.
Aug. 25–28: ARS-Northwestern Technological Institute Gas Dynamics Symposium, Northwestern University, Evanston, Ill.
Dec. 2–6: ARS Annual Meeting, New York.

Into Space

LAST month, top civilian and military scientists gathered in San Diego for a three-day Astronautics Symposium sponsored jointly by the Air Force Office of Scientific Research and Convair Division of General Dynamics Corp. After the symposium ended, it appeared that the United States had just been committed to the "space age."

If this proves to be the case, then the scientists themselves must assume full responsibility. Quickly and repeatedly they assaulted the aura of fantasy created by Jules Verne and his followers.

In opening the first session, Convair's Joseph T. McNarney and Charles L. Critchfield stressed the serious purpose of the symposium. And keynoter Brigadier General Hollingsworth F. Gregory, commander of the USAF Office of Scientific Research, expressed his pleasure "that the visionaries have been succeeded by scientists and industrialists."

Major General Bernard A. Schriever, commander of the USAF's Western Development Division and featured dinner speaker, further underlined the deadly serious side of this business by noting the close tie-in of this country's ballistic missile program with the development of space technology and the very real possibility that "in the long haul, our safety as a nation may depend upon our achieving 'space superiority'."

At the same time, General Schriever pointed out, the ballistic missile program, representing a concerted effort and resultant impetus of unprecedented magnitude, is responsible more than anything else, perhaps, for bringing about the recent tremendous advances in space technology. "I would be willing to venture a guess," said the General, "that 90 per cent of the unmanned follow-on projects that one could visualize for the future can be undertaken with propulsive, guidance and structural techniques presently under development in the Air Force Ballistic Missile Program."

Most significant, perhaps, in attesting to the complete break here between the words science and fiction were the number and nature of those who came. First figured for 150, attendance rose to approximately 600 by the end of the three-day meeting. And the names read like a "who's who" in jet propulsion.

"We Have Come To . . . " As spelled out in the opening session, the purpose of this symposium was to pinpoint the technical problems obstructing development of space technology. To accomplish this, the field of astronautics was broken down into six panel topics: re-entry, tracking and communications, environment and measurements, propulsion, orbits, and human factors.

At the conclusion of the symposium, it was generally agreed that the problems had been well defined and that, as a result, many would soon be solved.

On the Art and/or Science of Astronautics:

AFOSR-Convair Astronautics Symposium, February 18–20, 1957, San Diego.

"We believe flight outside the atmosphere is a reality that cannot and must not be minimized."—Brigadier General H. F. Gregory, *AFOSR.*

"Presently known devices appear to make flights around and to the moon, Mercury, Venus and Mars theoretically feasible. Multiple-stage devices being conceived can, with reasonable flight times, make it theoretically possible to fly missions to Jupiter and Saturn. There is no known powerplant today which would permit trips to Neptune or Pluto, or which would permit escape from the solar system in any reasonable length of time. We hope future discoveries will develop propulsion systems that will make this possible."—George P. Sutton, *North American Aviation, Inc.*

"Total cost for a five-year program to put four people on an artificial earth satellite would be $350 million. It would cost 12 times this to place them on Mars."—William H. Dorrance, *Convair.*

"Above 100,000 feet, the sky overhead is a black vault and the sun is a shiny white button. When you look straight down, the earth appears colorless. It seems to be moving away from you like a bubble down the drain."—Captain Iven C. Kincheloe, *USAF.*

"After science does all it can for the space crew and its craft, the rest must be charged off to calculated risk."—Colonel Paul A. Campbell, *USAF-(MC), AFOSR.*

"Fluorine compounds are a good bet for future oxidants . . . Propulsion in 1965 or beyond may be based on free radicals . . Ionic propulsion looks promising but there is no way of making large numbers of ions."—Y. C. Lee, *Aerojet-General Corp.*

"Chances are that a meteor would puncture the skin of a space vehicle once in four days."—Fred L. Whipple, *Smithsonian Astrophysical Observatory.*

"Propulsion will be the determining factor in space travel."—William Bollay, *Aerophysics Development Corp.*

"To circumnavigate the moon and come back, accuracy to within ± 1 fps out of an estimated velocity of 35,000 fps is needed; and to land, ±0.5 fps."—Hans A. Lieske, *Rand. Corp.*

"'Do unto others as they would have you do unto them' will be the Golden Rule of the space age."—Andrew G. Haley, *attorney; general counsel, American Rocket Society.*

(Continued on page 324)

How to cool a pilot in the Thermal T

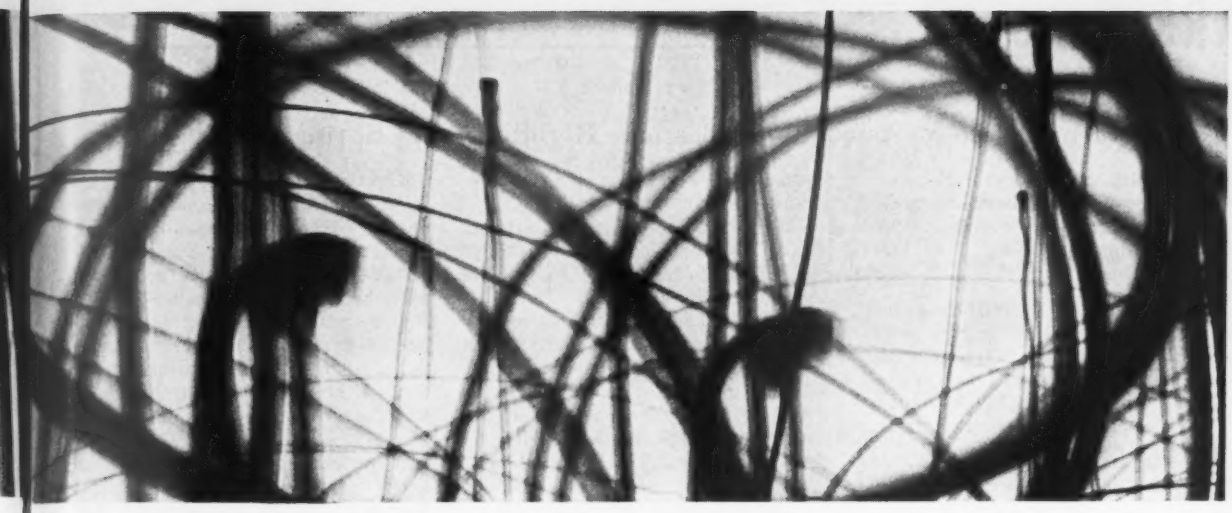
The Douglas X-3, used in heat dispersion studies.

With aircraft that top 1000 mph now in military service, the problem of *heat dispersion* gets growing attention from Douglas engineers.

Once called the heat barrier, science now uses a more accurate term, *thermal thicket.* The faster you fly through the earth's atmospheric blanket, the further into the thicket you get . . .

At Mach 2, twice the speed of sound, a plane's skin temperature can reach 275°F. At Mach 3 it leaps to 650°F, and at Mach 5 hardened steel wilts like lettuce . . .

Douglas is attacking this heat problem on many fronts. Air conditioners powerful enough to cool a theater were tested in the famous X-3 research plane seen at left. In current Douglas missiles, amazing advancements are being made in the design of heat-resisting materials and structures. This knowledge will speed the solution of the thermal thicket problem for piloted aircraft.



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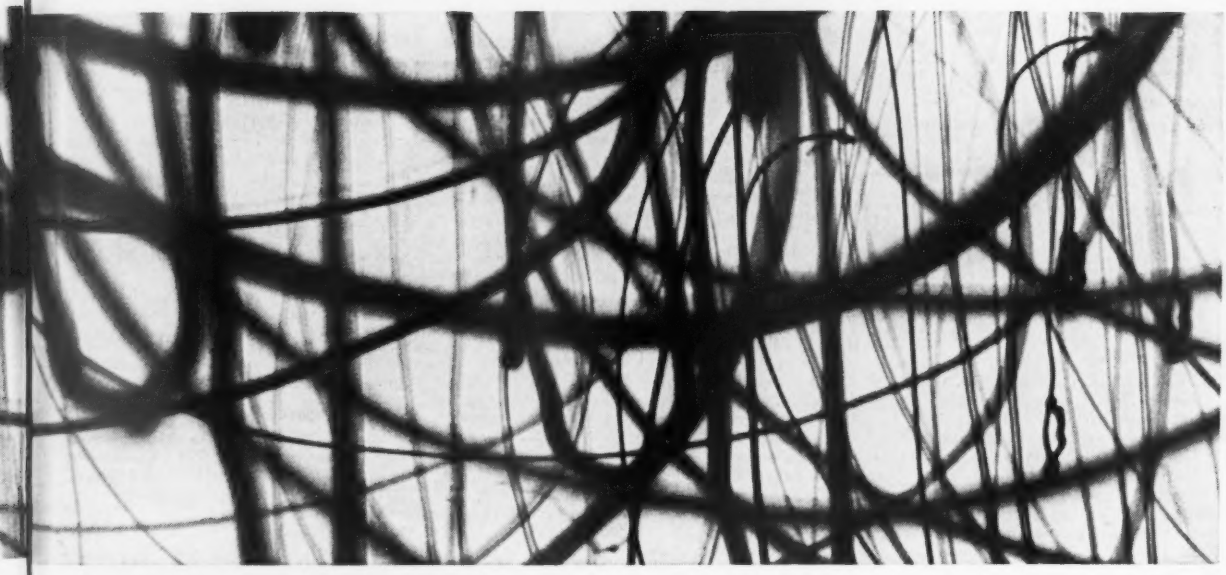

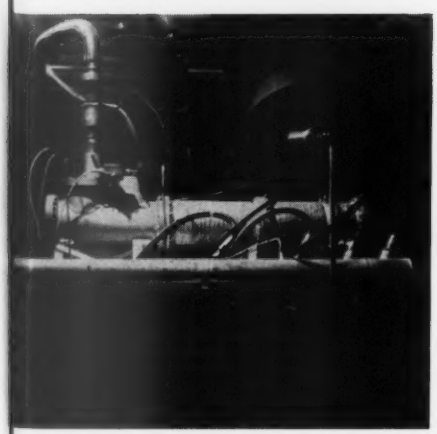

The Douglas Aero-rotor, an instrument that blasts out high velocity gas at temperatures upward of 3000 degrees Fahrenheit, helps in research for materials to withstand high temperatures and jet velocity erosion. Other work now on the boards at Douglas ranges from designs for the practical application of atomic power to the complete design and building of intercontinental missiles — and even includes the engineering for a space platform first considered as early as 1946.

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ARS News

April 4–6

Space Sociology, Astronautics Sessions Highlight ARS Spring Meeting

THE AMERICAN ROCKET SOCIETY and the Cherry Blossom Festival are due to arrive in Washington at the same time next month. It was planned that way.

But other than as a focus for social events and a reason for making hotel reservations early, the cherry blossoms have nothing to do with the Spring Meeting, set up by the AMERICAN ROCKET SOCIETY in cooperation with its National Capital Section.

As usual, the meeting's main concern will be with the technical sessions. This particular meeting will center on four main themes (see Program): high speed test tracks, space sociology, propulsive systems, and astronautics.

Between sessions, at the luncheons, receptions and banquet, members will have an opportunity to meet and listen to some of the world's top men in astronautics. Among those that will participate in the sessions: jet propulsion pioneer Theodore von Kármán, chairman of NATO's Advisory Group for Aeronautical Research and Development; Colonel John P. Stapp of rocket sled fame; and P. K. Roy, director of the legal bureau of International Civil Aviation Organization.

And, destined to be a top attraction at the Spring Meeting, there will be a special exhibit of rockets, satellites, and guided missiles along with related material and equipment. The exhibit, sessions, and registration will all take place in Washington's Sheraton Park Hotel starting with the mixer Wednesday evening (April 3) right through the final banquet on Saturday evening.

A. F. Spilhaus, Dean, Institute of Technology, University of Minnesota, will be the speaker at the banquet.

Credit for this meeting, which promises to be a big success, belongs in large measure to the National Capital Section. Individual kudos go to the many Section committees which have done so much to create a cohesive and interesting session and, in particular, to the following committee chairmen: Andrew G. Haley who as meeting chairman bears over-all responsibility for the affair; Erik Bergaust, president of the host Section, who handles public relations and exhibit liaison; William Roennau who obtains session aides; Robert Hirsch who is in charge of reservations; Jean (Mrs. Erik) Bergaust and Truda Jewett who look after the social activities; and, representing parent ARS, Kurt Stehling who this year is National Program Committee Chairman.

SPRING MEETING PROGRAM

Wednesday, April 3

10:00 a.m. — **Madison Suite**

Directors Meeting

5:30 p.m. — **Continental Room**

Mixer

(Courtesy of National Capital Section)

Thursday, April 4

8:00 a.m. — **Burgundy Room**

Breakfast

(Courtesy of North American Aviation, Inc.)

Panel Discussion on Missile Systems

9:30 a.m. — **Sheraton Hall (South End)**

Space Sociology—I

Chairman: John P. Stapp, Holloman Air Development Center, Holloman AFB, Alamogordo, N. M.

Vice-Chairman: P. K. Roy, International Civil Aviation Organization, (ICAO), Montreal, Canada.

✦ Opening Remarks and Moving Pictures Relating to Effects of Acceleration and Deceleration on the Human Being, by John P. Stapp, Holloman Air Development Center, Holloman AFB, Alamogordo, N. M.

✦ Some Current Considerations Affecting the Evolution of Space Law, by P. K. Roy, International Civil Aviation Organization (ICAO), Montreal, Canada. (388-57)

✦ Neuro-Endocrine Factors Essential for Survival in Space, by William R. Brewster and Majic S. Potsaid, Harvard University; James B. Isaacs, The Johns Hopkins University; Harriet Bullitt Brewster. (389-57)

✦ Physiological and Psychological Tolerance to Weightlessness, by Siegfried Gerathewohl, USAF School of Aviation Medicine, Randolph AFB, Texas. (390-57)

✦ Probable Influences of Satellites on Society, by N. Elliott Felt, Jr., The Martin Co., Baltimore, Md. (391-57)

10:00 a.m. — **Continental Room**

High Speed Sleds—I

Chairman: R. L. King, Experimental Track Branch, Edwards Air Force Base, Calif.

Vice-Chairman: Clifford T. Hurd, Experimental Track Branch, Edwards Air Force Base, Calif.

✦ Supersonic Track Facilities at the Naval Ordnance Test Station, by B. R. Egbert and D. P. Ankeney, U.S. Naval Ordnance Test Station, China Lake, Calif. (392-57)

✦ Design Considerations of Two Large Liquid Rocket Pusher Sleds, by H. Davies and D. S. Smith, Reaction Motors, Inc., Denville, N. J. (393-57)

✦ High Speed Test Track Instrumentation, by Warren H. Sanders, Holloman Air Development Center, Holloman AFB, Alamogordo, N. M. (394-57)

✦ Aberdeen Proving Ground Ballistic Track, by Mitchell E. Bonnett, Aberdeen Proving Ground, Aberdeen, Md. (396-57)

12:30 p.m. — **Sheraton Hall (North End)**

Human Factors Luncheon

(Courtesy of Chance Vought Aircraft, Inc., Dallas, Texas.)

Speaker: Theodore von Kármán, Chairman, Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organization, Paris, France.

2:30 p.m. — **Sheraton Hall (South End)**

Space Sociology—II

Chairman: Theodore von Kármán, Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organization (NATO), Paris, France.

Vice-Chairman: Andrew G. Haley, General Counsel, AMERICAN ROCKET SOCIETY, Washington, D. C.

✦ United Nations, Space Law and Metalaw, by Andrew G. Haley, General Counsel, AMERICAN ROCKET SOCIETY, Washington, D. C. (397-57)

✦ Space Flight and Our Technological Revolution, by Wernher von Braun, Army

Committee Chairmen—ARS 1957 Spring Meeting

Kurt Stehling
National Program

Andrew G. Haley
Meeting Chairman

Erik Bergaust
Public Relations

Jean Bergaust
Social Events

Truda Jewett
Social Events

W. H. Roennau
Session Aides

An Announcement

OF FIRST IMPORTANCE
TO EXPERIENCED ROCKET ENGINEERS AND SCIENTISTS

- *Reaction Motors initiating big new Research and Development Program*
- *Key spots offered to men who have already made a name for themselves in Rockets*

If you're one of the relatively few trained rocket men in America, your experience will pay off handsomely at Reaction Motors. The first rocket company in America, RMI is now entering its period of greatest expansion, a period that will see far-reaching developments in America's fastest-growing industry. Your participation in RMI's program during this crucial period is your best guarantee of leadership in the industry. In a job like one of those listed below you'll be strategically placed for both achievement and advancement.

1. SENIOR DESIGN ENGINEER

Prefer ME or AE degree and a minimum of 6 years' experience in aircraft engines or airframes You should have extensive design experience, including plenty of board time, shop contact, structural design, stress analysis. You will be working directly with design engineers and layout draftsmen on design of light weight, complex structures.

2. INSTRUMENTATION ENGINEER

BS minimum in mechanical, aeronautical or electrical engineering; 3–5 years' experience on aircraft engines. Must be familiar with the application of instrumentation to testing of rocket or other aircraft engines, the utilization of currently available instrumentation, or the modification and adaptation of such instrumentation for particular requirements and wide limits of flow temperatures, pressure, thrust, etc.

3. STRESS ENGINEER

Degree in engineering or applied mechanics. Required experience in mechanical design with emphasis on stress analysis: 3 years for an engineer, to 6 years for the senior engineer. Must be able to handle and/or supervise involved analyses–including the effects of dynamic forces, high temperature gradients and high pressure differentials–under conditions where light weight is vital.

4. PROJECT ENGINEER

BS or MS in ME, AE, or ChE–with at least 5 years' experience in the design, fabrication and test of rocket thrust chambers, gas generators and ignitors. Project engineers also needed with background which includes knowledge of principles and problems associated with design, development and analysis of hydraulic or pneumatic power plant controls and systems.

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Ballistic Missile Agency, Huntsville, Ala. (398-57)

✦ Astronautics, Public Relations and the Press, by Erik Bergaust, *Missiles and Rockets*, Washington, D. C. (399-57)

✦ The Function of Universities in Astronautical Research, by S. F. Singer, University of Maryland, College Park, Md. (401-57)

2:30 p.m. **Continental Room**

High Speed Sleds—II

Chairman: Henry J. Barten, Chicago Midway Laboratories, Eglin Air Force Base, Fla.

Vice-Chairman: H Davies, Reaction Motors, Inc., Denville, N. J.

✦ Supersonic Rain Erosion Testing on Missile Radomes, by K. Barr and E. J. Steeger, Edwards Air Force Base, Calif. (402-57)

✦ A Precision Data System for High Speed Tracks, by R. I. Anderson, Electronics Engineering Company of California, Los Angeles, Calif. (403-57)

✦ Design Determinants for the Holloman Horizontal Test Stand, by William T. Bateman, Holloman Air Development Center, Holloman AFB, Alamogordo, N.M. (404-57)

✦ Track-Testing at the Air Force Armament Center, by Richard K. Hendricks, Eglin Air Force Base, Fla. (405-57)

✦ Precision Measurement of Rocket Sled Velocity, by F. J. Beutler, Ramo-Wooldridge Corp., Los Angeles, Calif., and L. L. Rauch, University of Michigan and Ramo-Wooldridge Corp. (406-57)

Friday, April 5

10:00 a.m. **Continental Room**

High Speed Sleds—III

Chairman: Mitchell E. Bonnett, Aberdeen Proving Ground, Aberdeen, Md.

Vice-Chairman: J. Lechner, Coleman Engineering Co., Los Angeles, Calif.

✦ The Capabilities of the Holloman High Speed Track, by Gerhard R. Eber, Holloman Air Development Center, Holloman AFB, Alamogordo, N. M. (407-57)

✦ Design of Vehicles for High Speed Track Development Programs, by Richard A. Hirsch, Aircraft Armaments, Inc., Cockeysville, Md. (408-57)

✦ The Closed Circuit High Speed Test Track, by Henry J. Barten, Chicago Midway Laboratories, Eglin Air Force Base, Fla. (409-57)

✦ Track Testing at the Air Force Flight Test Center, by Ross R. Seger, Air Force Flight Test Center, Edwards Air Force Base, Calif. (410-57)

✦ Sled Testing the Emergency Escape System: The Human Factor, by James F. Hegenwald, Jr. and Edward A. Murphy, Jr., North American Aviation, Inc., Los Angeles, Calif. (411-57)

10:00 a.m. **Burgundy Room**

Propulsive Systems—I

Chairman: Clair Beighley, Aerojet-General Corp., Sacramento, Calif.

Vice-Chairman: Robert Schmidt, Naval Research Laboratory, Washington, D. C.

✦ Factors Which Influence the Suitability of Liquid Propellants as Rocket Motor Regenerative Coolants, by D. R. Bartz, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif. (417-57)

✦ Rocket Impulse Spectrum, by M. Farber, Aerojet-General Corp., Azusa, Calif. (418-57)

✦ Project Snooper, by M. I. Willinski and E. Orr, Rocketdyne, Canoga Park, Calif. (419-57)

2:30 p.m. **Burgundy Room**

Propulsive Systems—II

Chairman: Ivan E. Tuhy, The Martin Company, Baltimore, Md.

Vice-Chairman: E. Sheehan, Bureau of Ordnance.

✦ Techniques Used in Ramjet Engine Speed Control, by H. J. Nelson and R. B. Farrar, Bendix Products Division-Missiles, Mishawaka, Ind. (421-57)

✦ Design Considerations of the Vanguard Third Stage Rocket Engine, by Will Schaafsma, Grand Central Rocket Co., Redlands, Calif. (423-57)

✦ The Relation between Mission and Propulsion System in Missiles, by James M. Carter, Carter Laboratories, Inc., Pasadena, Calif. (420-57)

2:30 p.m. **Continental Room**

High Speed Sleds—IV

Chairman: R. K. Hendricks, Eglin Air Force Base, Fla.

Vice-Chairman: D. P. Ankeney, U. S. Naval Ordnance Test Station, China Lake, Calif.

✦ Redstone Arsenal Ballistic Ramp, by K. L. Carroll, Redstone Arsenal, Huntsville, Ala. (412-57)

✦ Mechanical Problems of Track Vehicle Design, by Richard F. Chandler, Holloman Air Development Center, Holloman AFB, Alamogordo, N. M. (413-57)

✦ The Development of the Rescu, Mark I, by H. F. Mohrlock, Convair, San Diego, Calif. (414-57)

✦ Liquid Rockets for Supersonic Sleds, by C. E. Roth, Jr. and H. M. Poland, Aerojet-General Corp., Azusa, Calif. (415-57)

✦ Measurements of the Vibration Environment in a Supersonic Liquid-Propellant Rocket Sled, by G. M. Barr and S. C. Morrison, The Ramo-Wooldridge Corp., Los Angeles, Calif. (416-57)

9:00 p.m. **Sheraton Hall**

Cherry Blossom Ball

Saturday, April 6

8:00 a.m. **Sheraton Hall (North End)**

Breakfast

(Courtesy of Grand Central Rocket Company, Redlands, Calif.)

Speaker: To be announced

10:00 a.m. **Continental Room**

Astronautics—I

Chairman: Kurt Stehling; Naval Research Laboratory, Washington, D. C.

Vice-Chairman: Donald Markarian, The Martin Company, Baltimore, Md.

✦ The Mechanical Aspects of the Vanguard Flight Control System, by F. Gordon Sholes, Jr., The Martin Company, Baltimore, Md. (424-57)

✦ Support Requirements of the Vanguard Satellite Launching Vehicle, by Sears Williams, The Martin Company, Baltimore, Md. (425-57)

✦ Army Support of Vanguard and a Dynamic Display System for Presenting Satellite Tracking Information, by Charles M. Parkin, Jr., and Edward J. Madden, Fort Belvoir, Va. (426-57)

10:00 a.m. **Sheraton Hall (South End)**

Astronautics—II

Chairman: N. Elliott Felt, Jr., The Martin Company, Baltimore, Md.

Vice-Chairman: Krafft Ehricke, Convair-Astronautics, San Diego, Calif.

✦ Design, Fabrication and Testing of First Man-Made Satellite, by Robert Bauman, Naval Research Laboratory, Washington, D. C. (427-57)

✦ Reentry of Spherical Bodies into the Atmosphere at Very High Speeds, by Krafft Ehricke, Convair-Astronautics, San Diego, Calif. (428-57)

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There isn't enough space in this full size outline to describe the stability, accuracy and reliability of the new Waugh Frequency-to-Voltage Converters. Please request Bulletin 103 for further details regarding direct indication or telemetering of Flow, RPM or Power Frequencies.
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Since 1951, M. W. Kellogg has been closely associated with the development and production of propulsion units for a wide range of missiles. Kellogg's most recent contribution is the development of reinforced plastic for rocket cases, using a unique filament winding method which produces structures of unparalleled accuracy and light weight.

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Ford Instrument Company's new Missile Development Division is expanding because of increased activity on guidance and control work for major ballistic missiles such as the Redstone and Jupiter.

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✦ Trajectories and Orbits of the Vanguard Satellite, by Benjamin Lepson, Naval Research Laboratory, Washington, D. C. (429–57)

✦ Rocket Measurement of Solar Flares, by T. A. Chubb, H. Friedman, J. E. Kupperian, and J. Lindsay, Naval Research Laboratory, Washington, D. C. (430-57)

12:30 p.m. **Sheraton Hall (North End)**

Power for Progress Luncheon

(Courtesy of Reaction Motors, Inc., Denville, N. J.)

Speaker: Major General David H. Tulley, Commanding General, Engineering Center, Fort Belvoir, Va.

7:30 p.m. **Sheraton Hall**

Banquet

Speaker: Athelstan F. Spilhaus, Dean, Institute of Technology, University of Minnesota, Minneapolis, Minn.

Presentation of Fellow Memberships to: Rear Admiral Rawson Bennett, Chief of Naval Research.

Athelstan F. Spilhaus, Dean, Institute of Technology, University of Minnesota.

Alan T. Waterman, Director, National Science Foundation.

On Astronautics

(*Continued from page 317*)

"We can go into space with today's chemical rockets. And it is likely that the first trip into space will be with chemical rockets because they are technically proven (known). Other propulsion systems hold greater potential but are not known. . . . Good ion rockets could be built today. A good photon rocket could not be built today but would open vistas not possible to conventional vehicles of today; e.g., travel to the whole universe."—Ernest Stuhlinger, *Redstone Arsenal.*

"Conditions achieved in ground laboratories don't exactly reproduce actual space conditions. Therefore we must take to the air with our experiments as soon as possible."—Major Stanley White, *USAF, Wright-Patterson Aero-Medical Center.*

"Possible answers to the problem of atmospheric heating upon re-entry are heat sink, porous cooling, materials which sublime at high temperatures, reaction of materials with atmosphere in shock layer. . . Further study of foreign atmospheres could uncover commercial possibilities involving the chemical processing of atmospheric constituents such as methane into acetylene, ammonia into hydrazine, etc."—Joseph Charyk, *Aeronutronic Systems, Inc.*

"For a 630-pound, spherical re-entry vehicle five feet in diameter, twenty-five per cent of total weight would have to be coolant."—Lester Lees, *California Institute of Technology.*

"Extended exposure to cosmic radiation at 120,000 feet doubles the mutation rate from two to four per cent."—Herman J. Schaefer, *Naval School of Aviation Medicine.*

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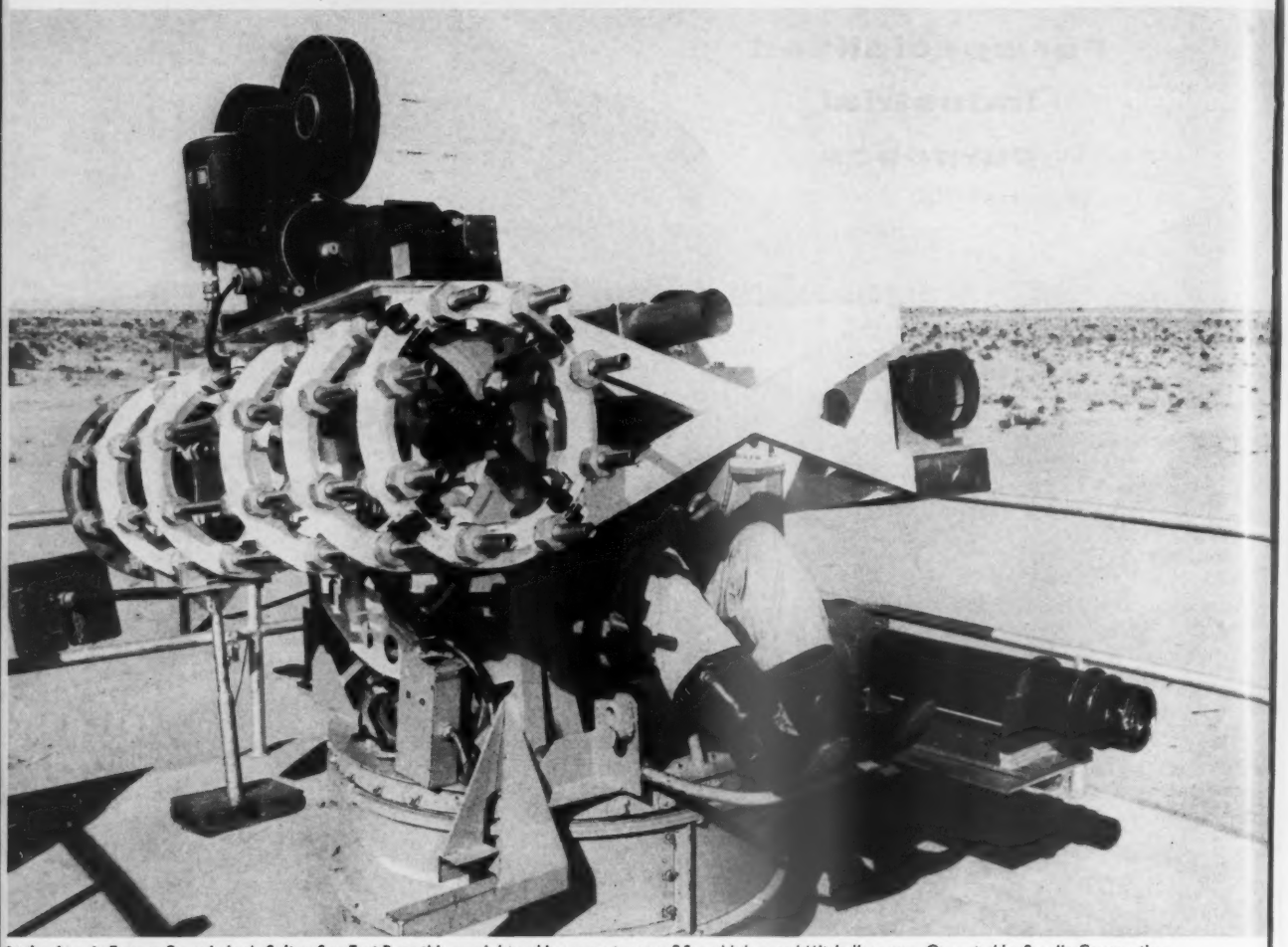
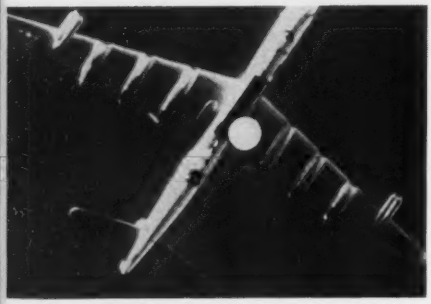


At the Atomic Energy Commission's Salton Sea Test Base this special tracking mount uses a 35mm high speed Mitchell camera. Operated by Sandia Corporation, his base uses Mitchell cameras for recording test operations.



Tracking at 40,000 feet, this film frame from a Mitchell camera operating at 96 frames per second provides an accurate record.

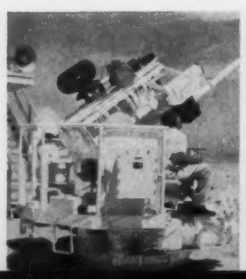
Salton Sea Test Base Uses Mitchell Cameras to Capture High Speed Action of Dummy Bombs

High speed flight and laboratory tests, which hitherto have been difficult or impossible to view with the human eye, are today providing revealing information through high speed film recordings.

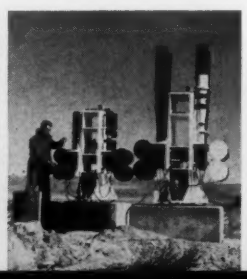
Typical example of the widespread use of high speed cameras is the Salton Sea Test Base in Southern California, where drop testing of "dummy" bombs is a major activity. In testing carried on there, by Sandia Corporation for the Atomic Energy Commission, as many as 20 Mitchell high speed cameras may record different angles in the flight of an experimental weapon "shape" from drop aircraft to impact area.

Operating at 48 to 100 frames per second, the Mitchell cameras film accurate, steady images with maximum uniformity—even under difficult and complicated filming conditions.

Mitchell cameras play a growing role in today's research and development—just as 16mm and 35mm Mitchell cameras have become the leading professional motion picture equipment used by industry, television, and film studios throughout the world. Write on your letterhead for further information on the uses of Mitchell cameras in the field of military and industrial research.



High speed Mitchell Camera in operation on tracking telescope mount during test run at Salton Sea.



Photogrammetric mounts for 8 Mitchell cameras determine the position in space of a nuclear explosion.

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Four More

QUALIFIED by reason of their work in the area of rocket or jet propulsion, four more firms were recently approved for corporate membership in the AMERICAN ROCKET SOCIETY. They are:

• Allied Research Associates, Inc., of Boston, Mass. This company specializes in, among other things, research and development of weapons effects, aerothermodynamics, missile design, structural dynamics, physics and physical chemistry, electronics, and instrumentation.

Representing the firm in ARS activities will be: Lawrence Levy, president; Joseph Kelley, Jr., vice-president; Norman Buchbinder, treasurer; Daniel J. Fink, chief project engineer; Claude W. Brenner, project engineer.

• Callery Chemical Co. of Callery, Pa. Callery is involved in research, development, and production of high energy fuels.

Designated as ARS representatives: E. G. Sanner, president; W. H. Shecter, vice-president-operations; J. S. Bardin, Muskogee Project manager; G. F. Huff, research and development manager; R. A. Mulholland, market development manager.

• Cornell Aeronautical Laboratory, Inc., of Buffalo, N. Y. Activities at CAL cover most phases of aeronautical research.

Staff members selected for membership in the SOCIETY: Ira G. Ross, director; A. H. Flax, assistant director; R. H. Shatz, head of systems research; F. K. Moore, head of aerodynamics research; R. W. Kluge, head of weapon systems design.

• Misco Precision Casting Co. of Whitehall, Mich. Misco produces precision investment castings for jets and rockets.

Designated as corporate representatives: T. Operhall, president and general manager; J. Cadieux, plant manager; C. Yaker, plant manager; K. J. Yonker, sales manager; C. W. Schwartz, technical director.

ARS Forms Six Technical Divisions

THE AMERICAN ROCKET SOCIETY last month announced the formation of six Technical Divisions designed to encourage broader participation by its members in ARS activities.

The six divisions are the Instrumentation and Guidance Division, Liquid Rocket Division, Propellants and Combustion Division, Ramjet Division, Solid Rocket Division, and Space Flight Division.

In a letter from ARS President Robert Truax, members were invited to join two of these divisions. In his letter, Commander Truax pointed out

Oil free high pressure gas

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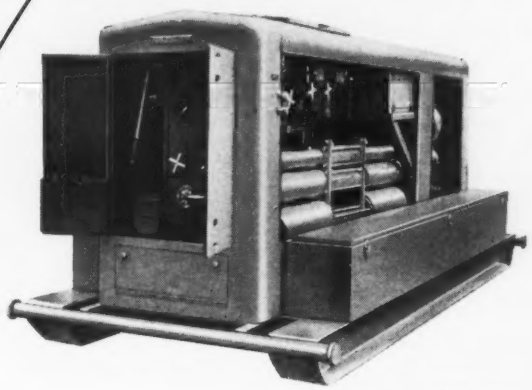

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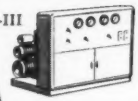
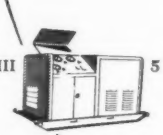


FOR TEST SITES — STATIONARY

MODEL SM-III 5 TO 30 SCFM



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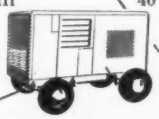
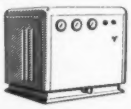
AVAILABLE WITH ELECTRIC MOTOR OR GASOLINE ENGINE

MODEL LM-III 40 TO 80 SCFM



FOR TEST SITES — PORTABLE
ELECTRIC MOTOR DRIVE – AIR COOLED

ASSEM. NO. 9315 1 SCFM



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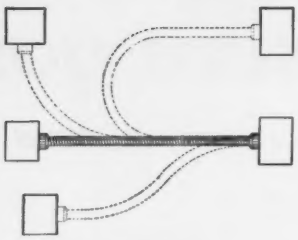

Before the innovation of Flexible Shafting, it was necessary to transmit power from a drive unit to its driven unit by means of a solid shaft which utilized expensive and cumbrous gearing. Today the Flexible Shaft alone provides a means of transferring this power from one unit to another by going around, over, and under obstacles. This allows you more space in your design, and eliminates the age old problem of having to have perfect alignment of the shaft and its drive or driven unit in order to make a connection. Flexible Shafts are simply curved towards the unit and connected by means of a ferrule, or an end fitting. If you have any application, now or in the future, which will require control from remote places, you owe it to yourself to write F. W. Stewart Corporation, 4311 Ravenswood Ave., Chicago 13, Illinois, for complete information on Circle Ess Flexible Shafting.

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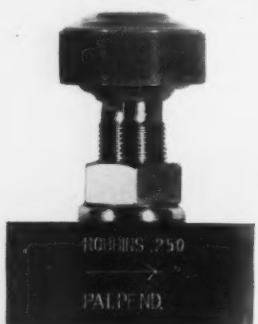

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- Impossible to score needle or seat.
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that membership in a division is not obligatory but would allow participation in the particular work of the division selected. No extra dues are involved in joining a division.

The first step toward the establishment of technical divisions was taken last year with the formation of six ARS Technical Committees. At its first meeting in 1957, the Board of Directors decided to proceed with the formation of these divisions, in which the entire membership could participate, under the leadership of the Committees.

In 1957 ARS Membership Roster will include division listings for each member.

Fields covered by the various divisions, along with Committee Chairmen and members, are as follows:

Instrumentation and Guidance Division—Missile guidance and control; piloted aircraft navigation and control; ground and flight instrumentation of rocket and ramjet engines and vehicles using these engines; instrumentation of related equipment and processes. Committee Chairman: John J. Burke, Hallamore Electronics Co. Vice-Chairmen: F. W. Lehan, Ramo-Wooldridge Corp. and R. J. Parks, Jet Propulsion Laboratory. Committee: J. T. Mengel, Naval Research Laboratory; Clayton E. Evans, Headquarters, ARDC; W. F. Sampson, Hallamore Electronics Co.; D. Follan, Convair-Astronautics; and J. Wisniewski, Glenn L. Martin Co.

Liquid Rocket Division—Liquid propellant rocket powerplants; vehicles or other devices using these powerplants; testing methods for liquid rockets; liquid propellants and related equipment. Committee Chairman: Edward N. Hall, Western Development Division, Air Research and Development Command. Committee: Paul Castenholz and Robert Dillaway, Rocketdyne; Stewart Johnson, Ramo-Wooldridge Corp.; Douglas MacCallum, Douglas Aircraft Co.; Chandler C. Ross and Robert B. Young, Aerojet-General Corp.; Arthur P. Adamson, General Electric Co.; Joseph Piselli, Bell Aircraft Corp; and Robertson Youngquist, Reaction Motors, Inc.

Propellants and Combustion Division—Rocket propellants; ramjet fuels; combustion processes; production and handling of fuels and propellants. Committee Chairman: John F. Tormey, Rocketdyne. Committee: Don L. Armstrong, Aerojet-General Corp.; Cecil Warner, Purdue University; Johann G. Tschinkel, Redstone Arsenal; David Altman, Aeronutronic Systems, Inc.; John Happel, New York University; Thomas F. Reinhardt, Bell Aircraft Corp.; Douglas H. Ross, Allied Chemical and Dye Corp.; Chester N. McCloskey, Office of Naval Research; and Alexis W. Lemmon, Jr., Battelle Institute.

Ramjet Division—Ramjet powerplants and all vehicles using these powerplants; testing methods for ramjets; ramjet fuels and related equipment. Committee Chairman: Brooks T. Morris, Marquardt Aircraft Co. Committee: Franklin P. Durham, University of Colorado; James W. Mullen, Experiment, Inc.; and William B. Shippen, The Johns Hopkins University.

Solid Rockets Division—Solid propellant rocket powerplants; all vehicles or other devices using these powerplants; testing methods for solid propellant rockets; solid propellants and related equipment. Committee Chairman: William L. Rogers, Aerojet-General Corp. Vice-Chairman: Ivan E. Tuhy, Glenn L. Martin Co. Committee: Emil A. Malick, Phillips Petroleum Co.; C. Dana McKinney, Jr., Hercules Powder Co.; Harold W. Ritchey, Thiokol Chemical Corp.; Geoffrey Robillard, California Institute of Technology; William Schaafsma, Grand Central Rocket Co.; and Clarence E. Weinland, U. S. Naval Ordnance Test Station.

Space Flight Division—Long range ballistic rockets; space vehicles; space navigation; space medicine; trajectories and orbits in space; physics of space; space law and sociology; space vehicle propulsion systems; space power supplies and support equipment; space communications. Committee Chairman: Krafft A. Ehricke, Convair-Astronautics. Committee: K. J. Bossart, Convair-Astronautics; George H. Clement, The Rand Corp.; George D. Colchagoff and William O. Davis, Headquarters, ARDC; Frederick C. Durant III, Arthur D. Little, Inc.; Andrew G. Haley, Haley, Doty and Wollenberg; Richard W. Porter, General Electric Co.; Darrell C. Romick, Goodyear Aircraft Corp.; Milton W. Rosen and Kurt R. Stehling, Naval Research Laboratory; Alexander Satin, Department of the Navy; S. Fred Singer, University of Maryland; Hubertus Strughold, Randolph Air Force Base; and Wernher von Braun, Army Ballistic Missile Agency.

Sections Now Total 35

WITH the addition of Central Colorado, St. Joseph Valley, University Park, and Holloman Sections in the past few months, the total number of ARS Sections now stands at thirty-five.

A charter presentation was made to the Central Colorado group at Lowry Air Force Base, Denver, on February 5 by James J. Harford, ARS Executive Secretary. Receiving the charter for the Section was John R. Youngquist of Martin-Denver, president. Other officers are G. P. Townsend, Sundstrand-Denver, vice-president; R. C. Lea and

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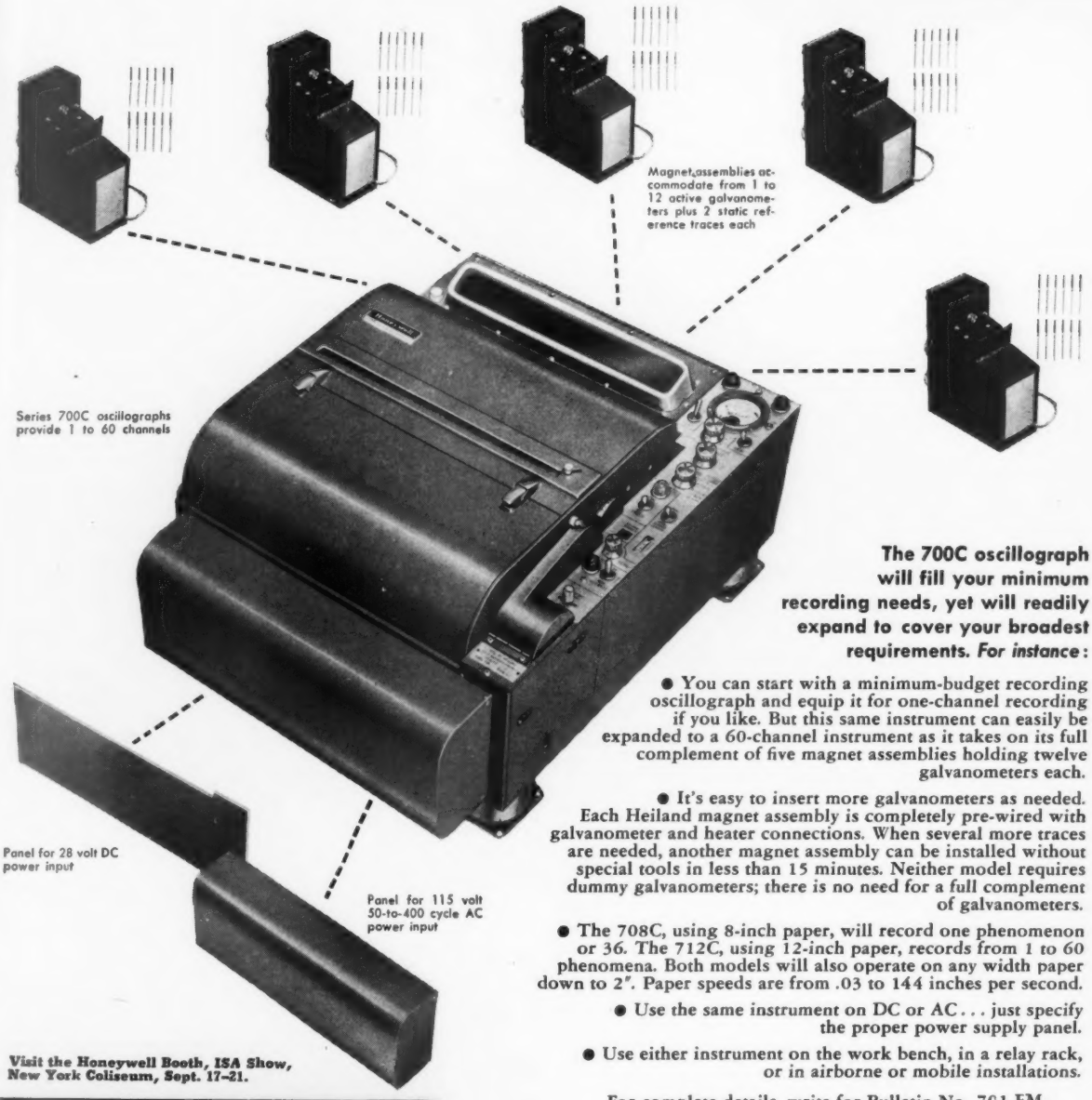
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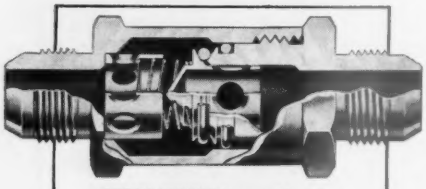

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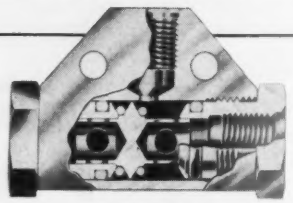

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R. B. Demoret of Martin-Denver, secretary and treasurer, respectively.

The University Park Section, centered at Pennsylvania State University, received its charter from Mr. Harford on December 10. Harold M. Hipsh, head of State's Aeronautical Engineering Department introduced Mr. Harford.

The Holloman Section was slated to receive its charter from ARS President Robert C. Traux on February 27 at Holloman AFB, N. Mex. Gerhard Eber is president of this group and his officers and directors include: Paul D. Jose, vice-president; Randolph A. Becker, secretary; Joseph A. Bedinger, treasurer; and directors John P. Stapp, David G. Simons, Bernard D. Gildenberg, Gerhard W. Braun, and James S. Hanrahan.

The St. Joseph Valley Section, although it has not had its charter ceremony as yet, has already staged several successful meetings under its president, C. M. Shaar, chief project engineer of Bendix Missile Section, Mishawaka, Ind. William H. Avery of Applied Physics Laboratory, The Johns Hopkins University, addressed a January meeting on ramjets; and Mr. Harford spoke on ARS before a February gathering. Other officers are: R. E. DeFrees, vice-president; C. R. Russell, secretary; and C. Ellsworth, treasurer. All are associated with Bendix.

The complete lineup of Sections and their presidents is as follows:

Alabama: Cliff E. Fitton, Redstone Arsenal
Antelope Valley: Richard A. Schmidt, Edwards Air Force Base
Arizona: Sidney Wade, Hughes Aircraft.
Central Colorado: J. R. Youngquist, Martin-Denver
Central Texas: E. F. Fiock, Phillips Petroleum Co.
Chicago: Gerald M. Platz, Armour Research Foundation
Cleveland-Akron: Adelbert O. Tischler, Lewis Flight Propulsion Laboratory, NACA
Columbus: M. W. Jack Bell, North American Aviation, Inc.
Connecticut Valley: Charles H. King, Jr., United Aircraft Corp.
Detroit: Charles W. Williams, Chrysler Corp.
Florida: R. L. Yordy, Pan American World Airways, Inc.
Fort Wayne: Roy Jackson, Farnsworth Electronics Co.
Holloman: Gerhard R. Eber, Holloman Air Force Base
Indiana: James A. Bottorff, Purdue University
Maryland: Andrew W. McCourt, Westinghouse Electric Corp.
National Capital: Erik Bergaust, *Missiles and Rockets*
New England: Lawrence Levy, Allied Research Associates, Inc.
New Mexico–West Texas: George L. Meredith, White Sands Proving Ground
New York: Robert A. Gross, Fairchild Engine Division

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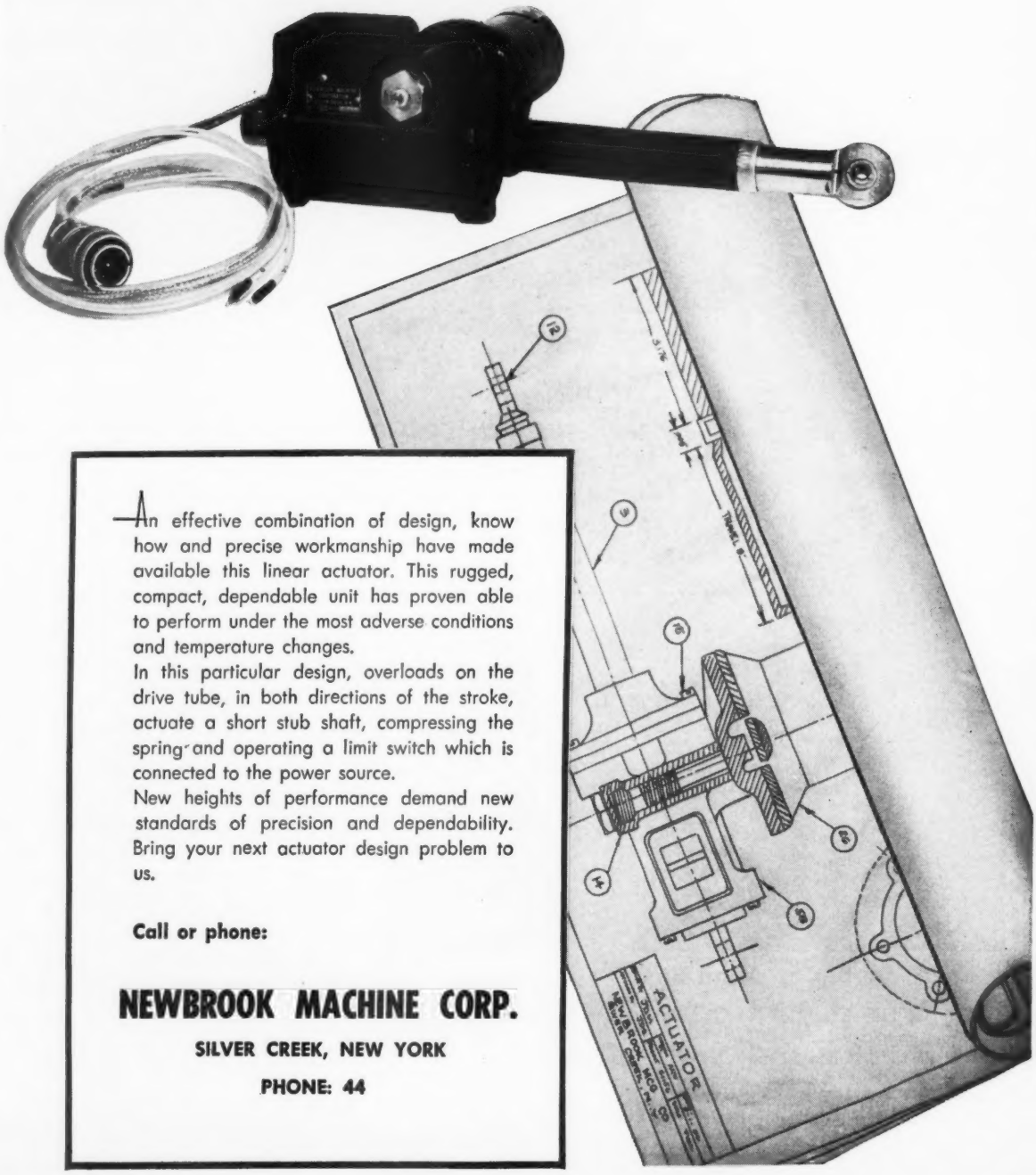

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Northeastern New York: A. H. Fox, Union College
Northern California: A. K. Oppenheim, University of California
Pacific Northwest: W. Emmett Coon, Boeing Airplane Co.
Philadelphia: Abe Bernstein, Philco Corp.
Princeton Group: Jerry Grey, Princeton University
Sacramento: Daniel M. Tenenbaum, Aerojet-General Corp.
St. Joseph Valley: C. M. Shaar, Bendix Aviation Corp.
St. Louis: James J. Mazzoni, McDonnell Aircraft Corp.
San Diego: Krafft Ehricke, Convair
Southern California: James A. Broadston, Rocketdyne
Southern Ohio: Thomas P. Meloy, General Electric
Twin Cities: C. C. Chang, University of Minnesota
University Park: Harold M. Hipsh, (Faculty Advisor) Pennsylvania State University
Wichita: Lawrence J. McMurtrey, Boeing Airplane Co.

'Section Guide' Out

Copies of a recently prepared manual on ARS Section operation have been distributed to the officers of each of the 35 Sections.

The "Section Guide," a 27-page multilithed document, is based on the experiences of the ARS and other technical societies.

It deals with the duties of officers and committees, liaison with the national office, elections, finances, Section budgets, and the legal liabilities incurred by Sections. Appendices include a sample budget form, sample report on receipts and disbursements, an outline of steps suggested in organizing a new Section, sample Section bylaws and sample minutes of meetings.

Of particular help to Section officials is likely to be the page devoted to "Liaison with the National Office." This page gives a chronological outline of the responsibilities expected of the Section, its officers, and committees.

Those officers and committee chairmen who have not received copies of the publication are invited to request them from the Executive Secretary, AMERICAN ROCKET SOCIETY, 500 Fifth Avenue, New York 36, N. Y.

The 'Ayes' of Texas

AT THE Cattleman's Cafe in Fort Worth, the North Texas electorate counted their recently cast votes, found they had elected the above Section officers for 1957: (l. to r.) Charles Crabtree, vice-president; B. O. Robinson, treasurer; W. H. Bender, secretary; George Craig, president; and Jack Kerr, member-at-large.

High Flyer

CAPTAIN Iven Kincheloe, USAF test pilot who holds unofficial altitude record for manned aircraft (JET PROPULSION, Nov. 1956, p. 992), was guest speaker at the January 17 meeting of the Cleveland-Akron Section. His subject, appropriately enough, was experimental flight testing of high speed research and pre-production aircraft. With Kincheloe above are Louis Lazo (left) and Del Tischler (center), Section vice-president and president.

Sections

Arizona: The following 1957 officers moved into their posts officially at a meeting scheduled for last February 5: Sidney L. Wade, president; Robert M. Shuman, vice-president; Phillip Tannous, Jr., secretary; and Joseph Krancz, treasurer.

Columbus: William C. Cooley, manager of Systems Analysis Section of General Electric Co.'s Nuclear Propulsion Department, was the guest speaker at the January 10 meeting. In his talk on the "Present Status and the Future of Rocket Propulsion," Dr. Cooley discussed the possibilities of using fission and fusion reactions directly in the combustion chamber. He also talked about using a magnetic field to contain the extremely hot gases instead of depending solely upon metallic or ceramic walls.

Fort Wayne: Farnsworth Electronics Co. provided both men chosen by the electorate as this year's president and vice-president. They are, respectively, Roy Jackson and Franklin H. Brady.

Following the ballot count on December 17, John Bolam gave members a rundown on the ARS Annual Meeting which took place in New York last November.

Indiana: A tour through the Purdue University Jet Propulsion Center climaxed by firing of an experimental rocket motor was the high point of the Section's January 12 program. At the Center, members had an opportunity to learn a little about the many research projects underway there, most of which center about heat transfer and film cooling of rocket motors.

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In the past, this data has depended upon optical devices, triangulation systems with long base lines and precision limitations, modified radar equipment and data reduction methods often requiring months for computation. The immediate availability of data evaluation provided by the AN/FPS-16, now being built by RCA under cognizance of the Navy Bureau of Aeronautics for all services, is a great forward step in Range Instrumentation.

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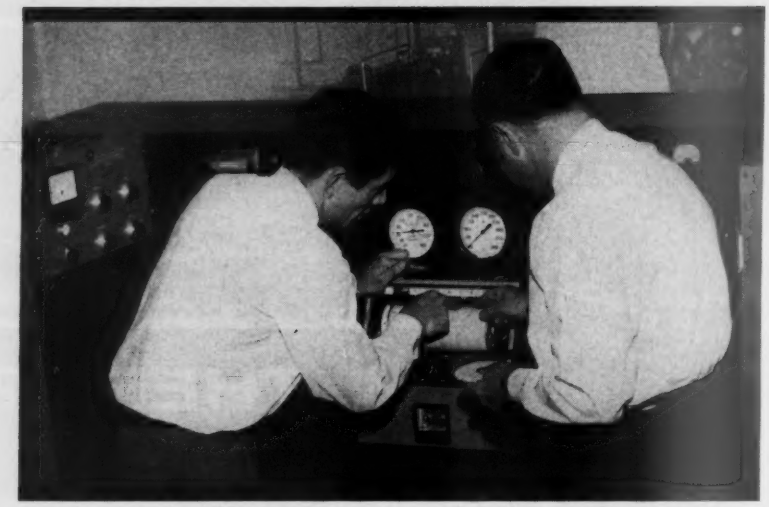

An example of Marquardt's progress and challenge is this new test instrument—designed and built by Marquardt Aircraft Co. engineers. The only one in existence, it was created to provide information on short time elevated temperature properties of materials utilized in supersonic missiles and powerplants.

Engineers are needed to conduct development programs aimed at establishing design and manufacturing criteria for the application of metals to ramjet engines. These programs cover a wide variety of structural materials and many different manufacturing processes.

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Maryland: On January 15, C. H. Dodge, project engineer with Aerojet-General Corp., gave members a fairly complete rundown on the Aerobee series of sounding rockets and their role in high altitude research.

New York: On January 11, some 200 members of the Princeton Group heard author Willy Ley predict that humans will occupy outer space satellites by 1982 and will land on the moon shortly thereafter. The problem, as seen by Mr. Ley, is not so much in getting there but in getting back again.

Northern California: At their annual meeting in San Francisco on January 17, members elected the following officers for 1957: A. K. Oppenheim, president; E. A. Quarterman, vice-president; F. I. Given, secretary; and L. A. Walker, treasurer.

Guest speaker for the evening was ARS President Robert Truax, who related history of early rocket development work in the U.S. Navy.

Pacific Northwest: Recent elections brought the following men into office for 1957: W. Emmett Coon, president; G. Truxton Ringe, vice-president; Walter B. Mills, secretary; and Richard H. Truly, Jr., treasurer.

San Diego: Mixing social hours, dinners and lectures, San Diego Program Chairman Neil O'Rourke came up with several interesting and well-attended meetings. On Oct. 9, guest speaker William H. Dorrance of Convair went into the problem of successful re-entry into the earth's atmosphere. Addressing the group on Nov. 13, John E. Naugle, also of Convair, concerned himself with the nature of cosmic radiation. Dr. Hubertus Strughold, featured speaker on Dec. 13, discussed medical problems involved in space operations.

Available

The AMERICAN ROCKET SOCIETY Committee on Monopropellant Test Methods has completed work on its second recommended test procedure. Titled "Minimum Pressure for Vapor-Phase Ignition," the compilation is now available from the AMERICAN ROCKET SOCIETY, 500 Fifth Avenue, New York 36, N. Y. Cost is $1/copy.

Purpose of this particular work and of the Committee is to establish standard procedures for testing monopropellants. Adoption of these carefully derived procedures by industry and government alike would then permit scientists to make direct comparisons of test results in this important field.

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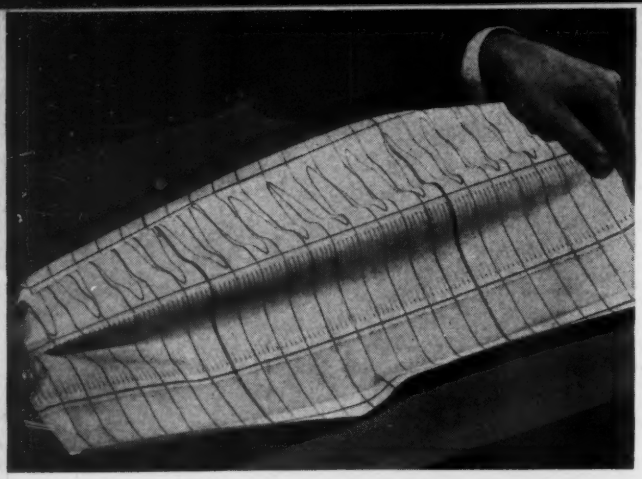

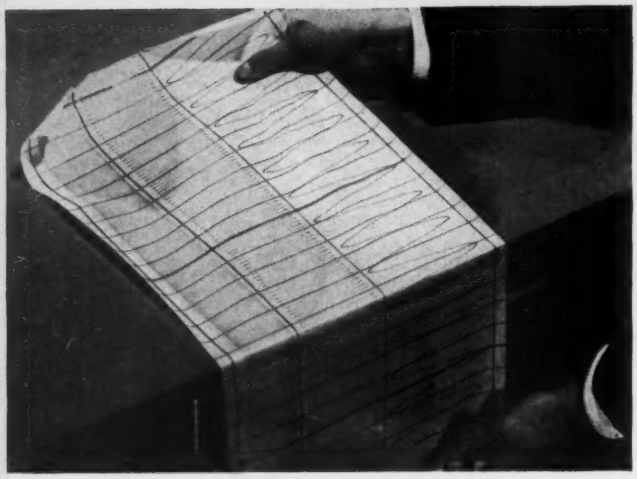

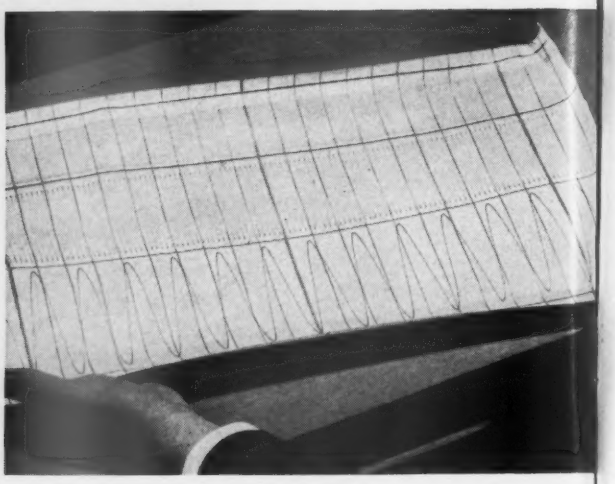

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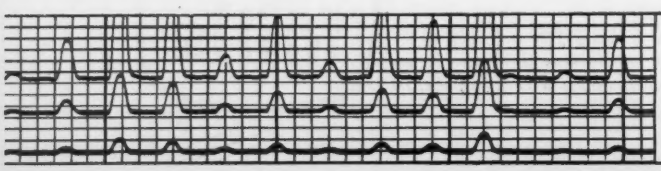

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Book Reviews

Ali Bulent Cambel, Northwestern University, *Associate Editor*

Gas Kinetics, by A. F. Trotman-Dickinson, Academic Press, Inc., New York, 1955; Butterworths Scientific Publications, London, x +322 pp. $8.

Reviewed by R. C. ANDERSON, University of Texas

The author notes that this is a critical survey of experimental results and a discussion of their significance, designed particularly for the undergraduate seeking a general account of gas kinetics and the beginning research worker seeking a key to the literature. "Gas kinetics" as used here refers to the chemical kinetics of strictly gaseous reactions and also such physical factors as molecular motion and energy transfer which play an essential role in the chemical processes. Major emphasis is, of necessity, placed upon the simple, elementary reactions since they are the only ones reasonably well understood.

It should be noted also that the reader is assumed to have a good background in physical chemistry. This includes, for example, concepts such as van der Waals' radii, entropy, and energy of activation. Some knowledge of statistical mechanical methods is also assumed; for example, some familiarity with energy surfaces and partition functions.

The author has accomplished his general purpose admirably. The book is well written and well organized. The basic theories of chemical kinetics are discussed clearly and careful consideration is given to the problem of transfer of energy in molecular collisions which is essential for any reaction.

The chapters dealing with various types of reaction and examples of these are particularly effective in the timeliness and scope of their coverage. A wide variety of atomic and free-radical reagents are covered. The discussion of these includes also many of the more recent experimental developments, such as the use of shock tubes, nitric oxide inhibition studies, flash photolysis and sector timing methods, and diffusion flames. Extensive references to the literature are made available.

This reviewer would differ with the author in his handling of oxidation reactions in the Preface rather than the text. The point is well taken that in most cases the mechanisms of these are not known (though it is certainly questionable, for example, that this applies to hydrogen-oxygen reactions). However, some of the contributions made in the study of oxidation and the questions they raise should not go without mention in a general treatment of gas kinetics. Problems such as those of nonequilibrium conditions of energy transfer and the significance of "temperature" in high energy systems; the variety and interplay of intermediates in many systems; and the role of branching reactions in chain mechanisms are of basic importance to the field.

Nonetheless, the book is an effective contribution to the literature. In addition to the two groups mentioned by the author it is also recommended to experienced workers in the field interested in a refreshing discussion of the present status of basic theories and also a good summary of a variety of experimental techniques and results.

Temperature, Its Measurement and Control in Science and Industry, vol. 2, edited by Hugh C. Wolfe, Reinhold, New York, 1955, 477 pp. $12.

Reviewed by ALLAN SCHAFFER Ramo-Wooldridge Corp.

This volume contains papers presented at the Third Symposium on Temperature, sponsored by the American Institute of Physics in 1954. The first such symposium was given birth in 1919 under the title "Symposium on Pyrometry." Twenty years later in 1939 another symposium was held and the proceedings bore the same title as the present book, which is considered as Volume 2 of the series. Only 15 years elapsed between the second and third symposia so that in the future we can, perhaps, expect a new volume every decade or so.

Volume 1 was a momentus work (126 papers, 1375 pages), and it has become a widely known reference. It served as a standard for the problems of its day, which were mostly in industry. Volume 2 is much smaller (24 papers, 467 pages), but it concisely covers the challenging temperature problems of today, which are mostly in science. Only one article in the present volume is devoted to commercial techniques and none to industrial problems. In contrast, a preponderance of Volume 1 was concerned with these subjects. This difference in the weighting of the subject matter between the two volumes serves as a commentary on the shift toward the scientific that has occurred in the last 15 years.

The present volume is well organized. The 24 papers are grouped into 5 sections entitled respectively: General Concepts, Standards and Scales, Transient Phenomena, Experimental Measurements, and Miscellaneous Topics. An attempt has been made to include in each section papers running the gamut from near absolute zero (0.001 K) to interior stellar temperatures (of the order of 100,000,000 K). Most of the subjects of current interest have been covered by one or more articles, and a distinguished group of authors have contributed. The papers are generally of a summary nature. Unfortunately there exists an inconsistency in the amount of detail in the various articles so that some tend to be too brief while others are extremely detailed. Any of the papers will provide the reader with at least an introduction to the subject discussed, and every paper contains a complete bibliography. These bibliographies will prove to many the outstanding contribution of the book.

A few of the papers that are most likely to be of interest to the readers of this journal will be mentioned. The first paper, entitled "The Temperature Concept," is concerned principally with the classical thermodynamic definition of temperature for an equilibrium system. It is of significance that this paper alone discusses the classical approach. The theme that pervades the book is the limitation of the temperature concept for nonequilibrium systems. Many authors discuss systems in which there is not equilibrium between the various energy manifestations, or not equilibrium within a given manifestation. These situations give rise to partial temperatures, such as rotational, vibrational, electronic temperatures, which are the concern of an informative article entitled "Relaxation of Partial Temperatures." Present day problems are forcing the approach toward temperature to become less phenomenological and more statistical. Temperature is being increasingly thought of as a parameter that describes the distribution of molecules among various energy levels. This statistical view complements the phenomenological approach to lend deeper understanding to the meaning of temperature.

Inhomogeneity and nonequilibrium are two aspects discussed in an article entitled "High Gas Temperatures." Measurements of such temperatures are described in "Ionization Measurements at High Temperatures" and in "Experimental Temperature Measurements in Flames and Hot Gases." This last article gives a good discussion of the meaning of temperature in flames. Furthermore, the author surveys almost all of the intensity distribution and radiance methods of flame temperature measurement. Unfortunately he gives little discussion of the excellent work of Strong and Bundy with sodium D-line reversal measurements in inhomogeneous temperature fields. Also he neglects to mention one of the most widely used techniques for measuring rapidly varying temperatures, the so-called modified D-line method developed by Millar, Winans, Uyehara, and Meyers. The article is nevertheless an excellent summary with a complete bibliography.

One of the most fascinating papers is entitled "Temperatures in Atomic Explosions." It describes the controlled production of temperatures comparable to those in the interior of stars. Interesting aspects are that thermal equilibrium is approached inside the core of the bomb and that there is a practical limit to the highest temperatures obtainable because of the heat capacity of electromagnetic radiation. A summary article of appeal to rocket enthusiasts is "Temperatures in the Upper Atmospheres." Other papers of special interest are "Astrophysical Temperatures," "Thermodynamics of Irreversible Processes and Fluctuations," "Sound Velocity as a Measurement of Gas Temperature," and "Temperature Measurement in Engineer-

ing." This last article gives an excellent survey of commercial instruments and techniques.

In summary, the reviewer believes that the present book constitutes a valuable and useful addition to the scientific library. The volume is a worthy second edition to what promises to be a series of standard references on temperature.

Nuclear Fuels, by D. H. Gurinsky and G. J. Dienes, D. Van Nostrand Co., Princeton, N. J., 1956, 364 pp. $7.50.

Reviewed by J. P. FRANKEL
Systems Laboratories Corp.

With the large number of documents which have appeared recently and the great publicity that attended the Geneva Conference last fall many technologists both in and out of the field of reactor technology have been impressed by the large amount of material which was declassified and exposed to public view for the first time. In no field is this more pronounced than in the field of reactor materials in general and fission fuels in particular. For instance, except for possibly a single report, it was not even known prior to Geneva outside of classified circles that fissioning fuels were subject to extreme distortions in use, although the mechanisms of this, the most severe damage encountered in uranium fueled reactors, had been debated in the secret literature for at least five years and is still not understood.

This situation has enabled the authors to present within the confines of a single book a large amount of information otherwise available only in the Geneva papers and scattered declassified documents. In this sense alone the book is well worth its price to readers interested in reactor fuel problems. Perhaps for the same reason the book will serve much better as a reference work than as a text.

The book has three parts: Metallurgy of Uranium and Thorium, Radiation Effects, and Solid and Fluid Fuels. The first part is a valuable collection of metallurgical data, well presented, but naturally limited by spatial considerations. It is unfortunate that the metallurgy of plutonium could not be discussed (presumably security restrictions prevented release of plutonium information at Geneva) and the number of different materials that could be discussed was considerably fewer than in the so-called AEC package of handbooks that have been available since Geneva, but the treatment is excellent as a prelude to the second part.

The second part of the book really has no equal in the published literature. It is an excellent summary of the state of our knowledge of irradiation effects. So, also, are the review articles that have appeared recently in periodicals, but the outstanding characteristic of this work is the section on the damage to fissionable fuels, especially with respect to dimensional stability. This problem is still unsolved, of course, at least in the sense that there is no satisfactory theoretical treatment of the problem, but with the publication of this book it is at last possible that unclassified research can be undertaken at universities.

The third section is a collection of the technological considerations (in contrast to economic considerations) with respect to the selection and manufacture of specific fuel types. The authors wisely confine themselves to systems of known characteristics, such as the fluid U-Bi system developed at the Brookhaven National Laboratory, but the reviewer cannot help wishing that the authors had included some (even speculative) considerations of fluid fuels that are molten fissionable materials or packed beds of fluidized solids, since these will undoubtedly play a significant role in the development of economical and lightweight nuclear power systems.

Reactor Shielding Design Manual, edited by Theodore Rockwell, III, D. Van Nostrand Co., Princeton, N. J., 1956, 472 pp. Illus. $6.00.

Reviewed by DONALD H. LOUGHRIDGE
General Motors Technical Center

The great increase in industrial interest in the nuclear power business since the Atomic Energy Act of 1954 has brought a serious need for the collection and coordination of vast quantities of engineering data bearing on the many design problems associated with reactors. Furthermore, such digestion of experimental facts and the theory underlying their interpretation must be made available to engineering colleges if the serious shortage of technical people in this field is ever to be satisfied. The Naval Reactors Branch of the AEC Reactor Division is to be congratulated on making available the necessary time of its technical director for the editing of such a compendium of information.

The book obviously cannot be used as a textbook; neither is it a handbook. It will serve as an invaluable reference book for those in industry and universities who are confronted with the problem of adequate shielding of the various radiations produced by the fission process. A partial listing of chapter headings, such as basic theory, allowable radiation levels, core shielding, cooling system shielding, shield engineering, radioactivity of shut-down system, and effect of geometry of radiation source, shows the extent of coverage.

Much of the data are presented in the form of tables and graphs, and the size of the book ($8 \times 10^1/_2$ in.) allows these to be printed large enough so that accurate use can be made of them. The printing is excellent and the mathematical derivations are clear and in most cases fully developed. In any future edition, however, it is to be hoped that a little more care will be exercised in the selection of the best form of derivations, as sometimes one has the impression that too many equivalent derivations of a given result have been included. No serious typographical errors were noted. Nevertheless, the book will be of much use to both scientists and engineers involved in reactor design.

It is to be hoped that a similar volume covering the field of reactor theory and its experimental verifications will be soon available. The present text should serve as an excellent example of a useable format.

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Rockets and Guided Missiles, by John Humphries, MacMillan, New York, 1956, 230 pp. $6.

Reviewed by KURT STEHLING
Naval Research Laboratory

Another book on rockets and guided missiles has been added to the already extensive list of titles produced by British writers during the past 15 years or so. Although rocket and missile research in Great Britain has sadly lagged because of official apathy, the writers and dreamers have suffered no such restriction. They have produced many excellent books on space flight and rocket propulsion. This book by Humphries is no exception to this trend.

The book covers a wider spectrum of rocket and missile science than any other this reviewer has seen. The author, in 230 pages, 121 illustrations, and 22 tables manages to present something of the historical background, solid and liquid propellants and motors, rocket motors, rocket motor components, propellant and motor testing, missile guidance and aerodynamics.

After this "Jato" takeoff and nothing daunted, the author grapples with short and long range aerodynamic and ballistic missiles, research missiles and testing, aircraft propulsion, rocket applications and nuclear energy and space flight.

Then he tops off this rich fare with an appended bibliography of more than 100 references, all of them indexed in the text. The author's specialty (propulsion) has, not unreasonably, driven him to devote 100 pages to rocket motors and propellants and less than 20 pages to missile guidance and aerodynamics. This is unfortunate, since this book is purportedly written for the "non-engineers with a practical turn of mind and beginners entering this field of work." Therefore this group of readers may receive the impression (not uncommon even among technical people) that guidance and control, aerodynamics and structures are not as important as propulsion.

The text is liberally garnished with the by-now somewhat moss-covered examples of World War II German missile practice. The author, perforce, had to trot these out because of the paucity of British missile enterprises and the logistic and security problems associated with obtaining American guided missile data.

Chapter 13 on "Miscellaneous Rocket Applications" has an interesting and readable account of German torpedoes and submarines powered by rather specialized engines burning concentrated hydrogen peroxide and various fuels. While these applications are not, strictly, examples of rocket usage, they show the versatility of peroxide as an oxidizer.

The author concludes with the hopeful statement that "the satisfactory application of nuclear energy or the stabilizing of monatomic hydrogen, will make the missile of two decades hence as great an advance over present day missiles as the De Havilland Comet is over the Wright Biplane."

This is a good and logical ending, although one might wish that the author could have used for comparison some other aircraft instead of the Comet.

Dr. Lloyd H. Wilson (left), Thermodynamics Section engineer, discusses comparisons between theory and free flight test experimental data on boundary layer transition in hypersonic flow with Maurice Tucker (center), head of the Aero and Thermodynamics Department, and Thermodynamicist Karl G. Reseck.

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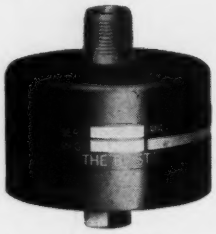

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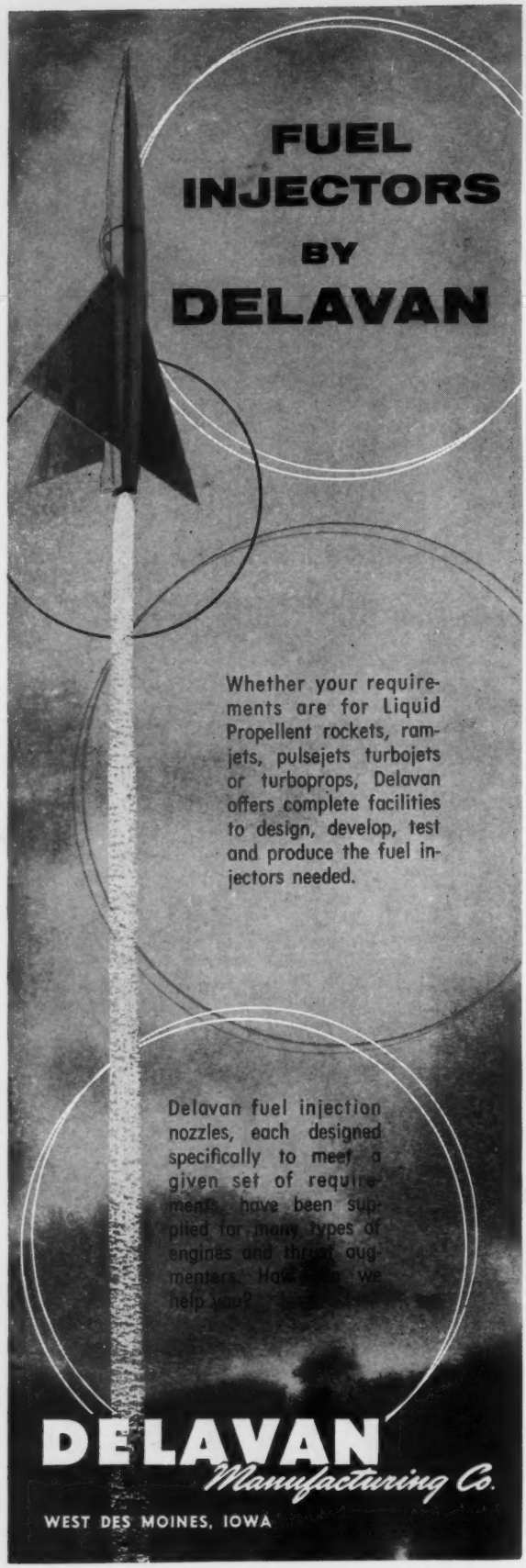

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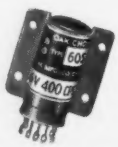

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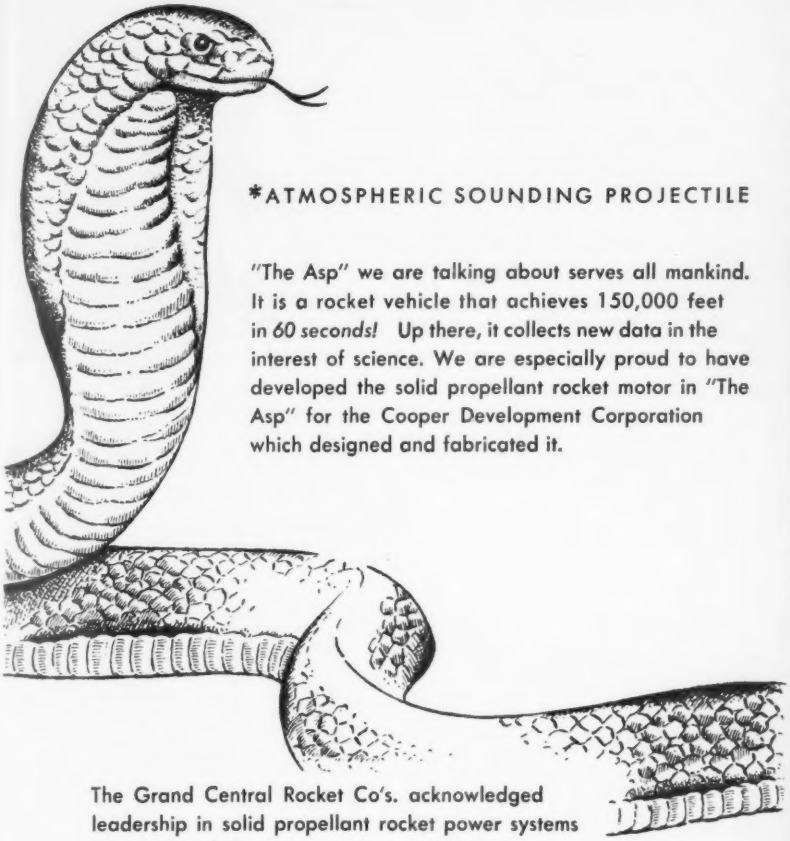

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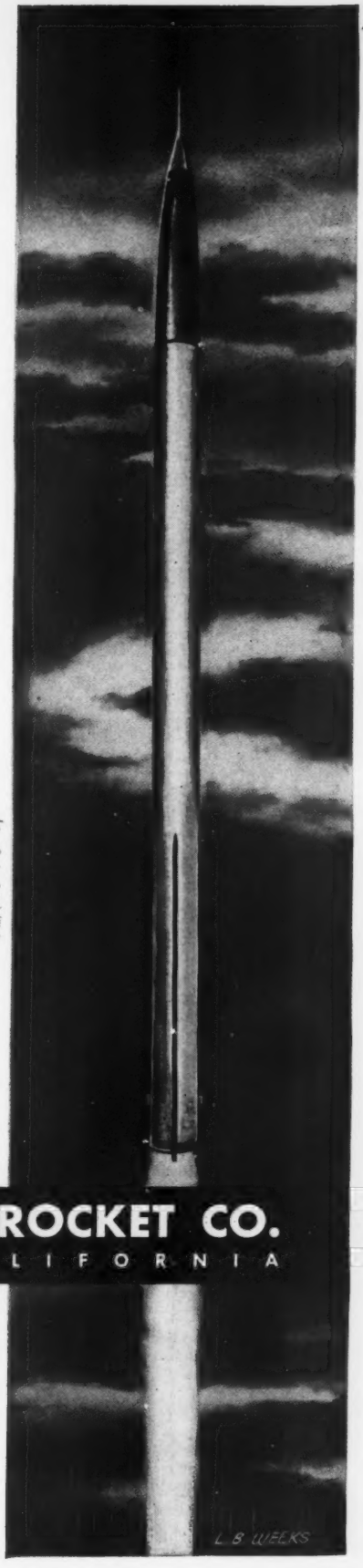

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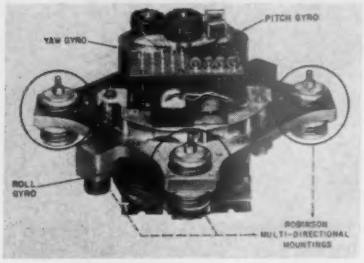

Dry Oscillograph. Penless, operates on xerograph process. Multichannel models. Instruments Inc., Tulsa, Okala.

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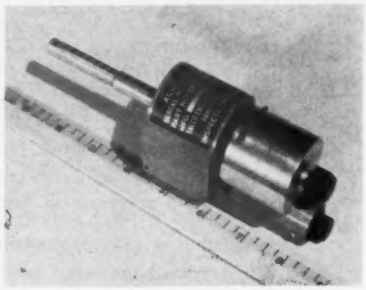
Titanium Descaling. The process requires only two immersion steps (one for scale conditioning, the other for removal) and two rinsing steps, following the heat forming or heat treating operation. Low temperature process (270-280 F) results in metal losses of 0.0001-0.0003 in. per side. Low hydrogen pickup; 100 per cent chemical clean without warping thin gages. Turco Products, 6315 S. Central, Los Angeles 1, Calif.

Dust Magnets. Ultra-fine, elongated iron particles are used to make powerful new magnets without using nickel or cobalt. The magnets are easily machined, drilled, tapped, soldered, and molded into any shape. General Electric Co., Instrument Dept., Lynn, Mass.



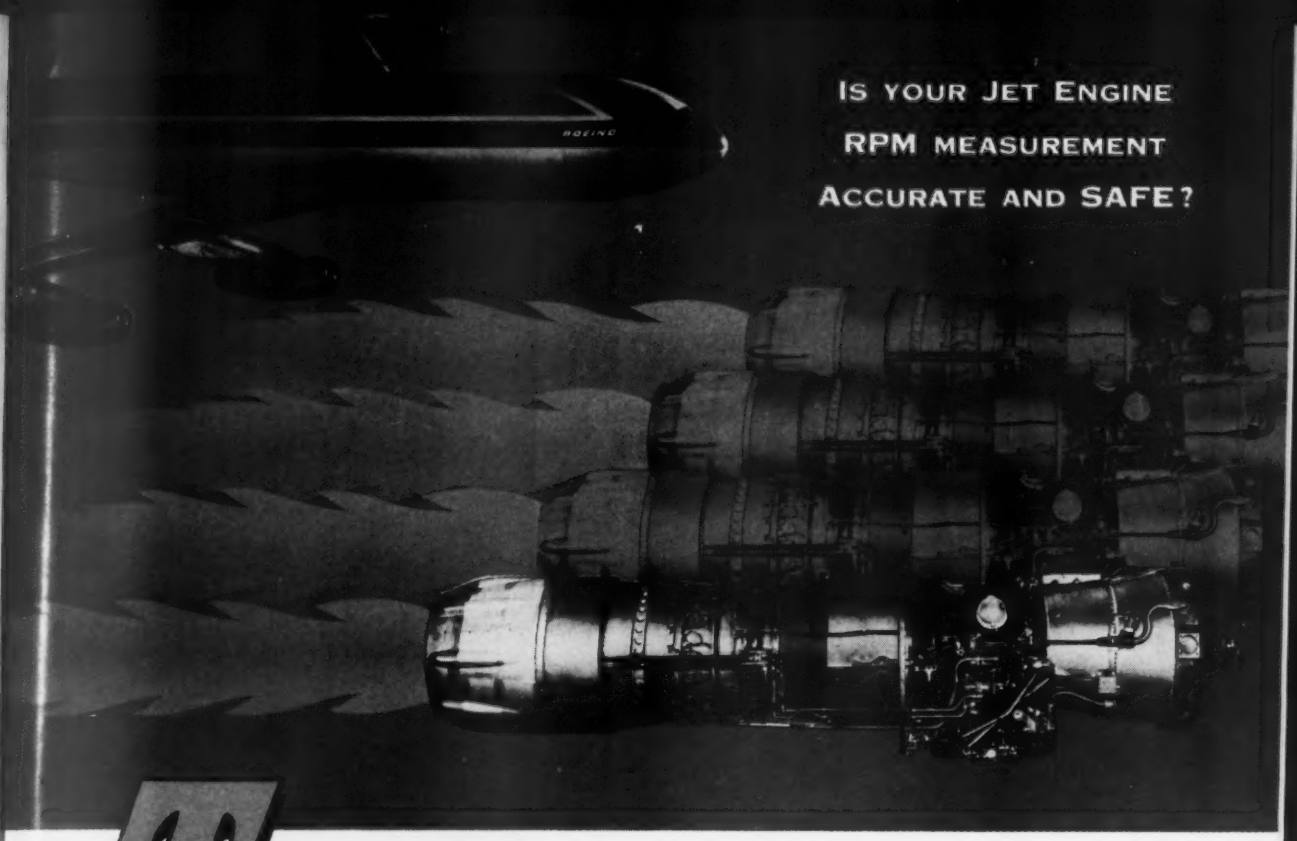
Auxiliary Devices. The growing list of solid propellant gas generators is reflected in the following new applications: **Cartridge Pull Unit.** Model 1002-1 produces a 4000-5000 lb retraction force for the first 11/16 in. of its stroke with a total stroke of 1-1 1/4 in. A cartridge produces 500-1000 psi gas. Unit weight is 1.8 lb. Talco Engineering Co., Hamden, Conn

Product Literature

Welding Graphite. The process operates in an atmosphere of inert argon gas under high pressure. The pieces to be welded are brought into contact and a d-c current is passed through them. The pieces are then separated slightly creating a high temperature arc. The combination of heat and pressure melts the graphite resulting in a weld instead of vaporization. National Carbon Co., 30 East 42 St., New York 17, N. Y.

Plastic Tooling. Digest of prices, applications, and resin selection. Covers epoxies and phenolics. Marblette Corp., 37–31 Thirtieth St., Long Island City 1, N. Y.

Gas Dehydration. Seven-page brochure covers line of dessicants, filters, purifiers. Robbins Aviation, 1735 Florence, Los Angeles 47, Calif.



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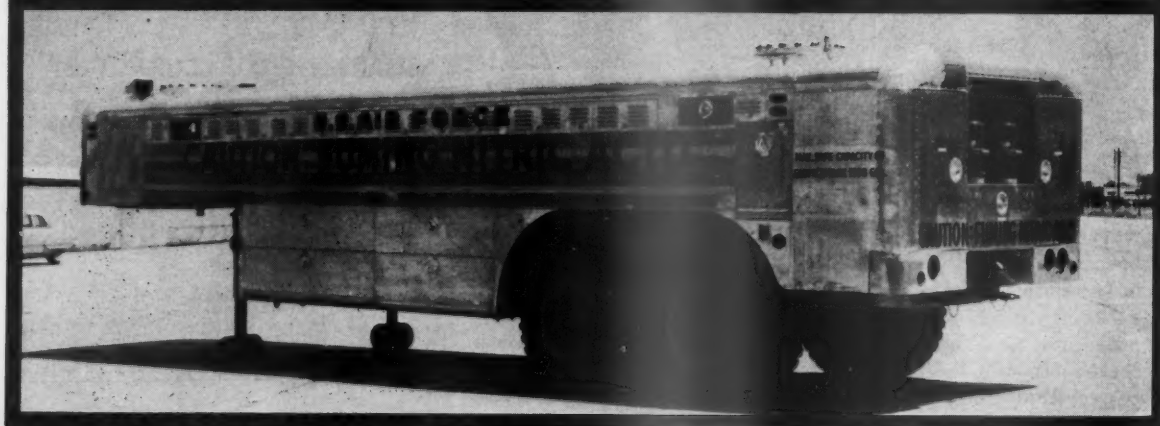

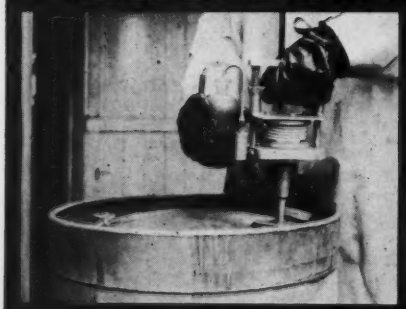

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New Patents

George F. McLaughlin, *Contributor*

Auxiliary fuel cell (2,777,656). John R. Clifton, Rolling Hills, Calif., assignor to Northrop Aircraft, Inc.

Jet airplane on which an area of the external surface (upper rear part of fuselage) is formed of an elastic material prestressed to maintain a predetermined surface contour position in flight. Fuel is inserted under pressure into a chamber of which the elastic material is the outer wall, distending the wall and increasing the capacity of the chamber.

Ram air driven turbine (2,777,524). James E. Chapman, Charles F. Drexel, and James E. Young, Los Angeles, Calif., assignors to The Garrett Corp.

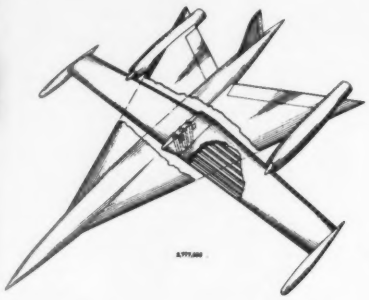
Flyweights coupled to adjustable pitch blades in a constant speed turbine. Torsion members tend to resist the centrifugal force developed by the flyweights when rotating, actuating a pitch-adjusting member.

Fluid sustained aircraft (2,777,649). Samuel B. Williams, Birmingham, Mich.

Helicopter with streamlined airfoil-shaped shrouds surrounding the rotor blades. Vanes direct incoming air downwardly to the rotor, and tiltable parallel blades control the direction of air discharged from the aircraft.

Tail pipe or afterburning control for turbojet engines (2,778,191). Thomas J. Thompson, South Bend, Ind., assignor to Bendix Aviation Corp.

Fuel is burned in an aft chamber in addition to that supplied to the normal burner system before the turbine. The quantity of fuel fed to one or more (but not all) burners is increased to cause a spurt of flame to project outwardly through the turbine into the aft chamber, with no substantial variation in engine speed.



Airplane with separable fuel tanks (2,777,655). Connelly L. Graham, Covina, Calif., assignor to Northrop Aircraft, Inc.

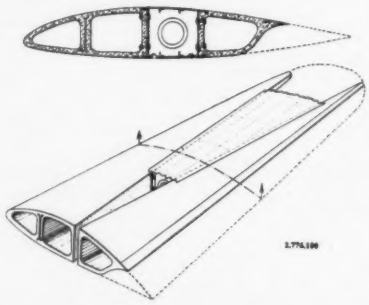
Means for increasing the performance and range of a supersonic speed jet aircraft. An auxiliary wing with an aerodynamic form suitable only for subsonic flight and containing fuel tanks, is attached below the airplane on a pedestal. A quick-release permits jettisoning the wing, pedestal, and tanks from the airplane during flight.

Ram jet engine (2,766,581). Harvey W. Welsh, Wycoff, N. J., assignor to Curtiss-Wright Corp.

An expendable ductlike section secured to and extending rearwardly from the main section, and releasable in flight.

Combustor basket structure (2,778,192). Pieter J. Kroon, Swarthmore, Pa., assignor to Westinghouse Electric Corp.

Open framework in which tubular members are supported in end-to-end overlapping relationship, providing a combustion chamber wall. The members, keyed to the framework, are removable by axial movement.



Aircraft structural elements and especially wings from reinforced concrete (2,776,100). Louis Breguet, Paris, France.

In a wing surface, a pair of spaced tapered concrete box members having lightweight elements bridging the space between. Nonstressed skin imparts an unbroken outer surface. The same construction may also be used for tail surfaces.

(Application for this patent was made in 1952. Although it does not apply solely to jet aircraft, it is mentioned here because of its novelty and the prominence of the patentee as an internationally famous pioneer in aviation. He was active in his company until his death about two years ago at the age of 75.)

Fuel supply and control means for turbines and turbo jets (2,776,537). Adolphe C. Peterson, Minneapolis, Minn.

Fuel is discharged from a distributing conduit to the combustion chamber between the primary air compressor and the primary turbine rotor.

Constant temperature air supply (2,776,562). Robert P. Davie, Jr., and Eugene L. Spearman, Jr., North Hollywood, Calif., assignors to North American Aviation, Inc.

Pressurized air connected to an enclosed receptacle in a wind tunnel. Heat storage material within the receptacle precludes the air from appreciably dropping in temperature.

Device for attaching auxiliary rockets to a flying machine (2,776,622). Roger A. Robert, Boulogne-sur-Seine, France.

Central collar on which rockets are arranged uniformly and parallel with the collar axis. Arms between the collar and rockets have resilient means deformable in the direction of the axis between each rocket and its supporting arm.

Weathercocking supersonic wedge diffuser for air inlets in aircraft (2,776,806). Donald H. Brendal, South Glastonbury, Conn., assignor to United Aircraft Corp.

Streamlined member protruding upstream of an inlet opening defined by a leading edge. The member extends aft within the opening, and the portion of the member extending upstream is pivoted at its aft end.

Hydrostatic pressure switch (2,777,028). James M. Kendall and George A. Henderson, Huntsville, Ala., assignors to the U. S. Navy.

Pair of insulated electro-conducting terminals within a missile casing, and a movable element for connecting them by yieldable means. Hermetically sealed fluid-filled chamber in the casing has a pair of spaced flexible diaphragms. Outward flexing of the diaphragms breaks the electrical connection between terminals.

Starters for prime movers such as gas turbines (2,775,865). Douglas F. Welch, Richard A. Bell, and Kenneth B. Randall, Coventry, England, assignors to The British Thompson-Houston Co., Ltd.

Starter provided with a gas inlet, a monofuel supply, a chamber with heating means, and second and third chambers with increasingly greater capacities. A conduit connects the outlet of the third chamber with the gas inlet.

Ram jet engines (2,775,867). Whitney Collins, Detroit, Mich., assignor to Continental Aviation & Engineering Corp.

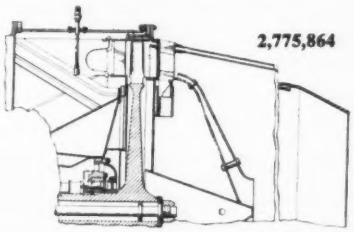
Pilot burner at the upstream edge of a flameholder, having an exhaust port and an inlet opening. The burner registers with the inlet to discharge a continuous annular flame into the sheltered zone of the flameholder.

Self-destruction device (2,775,942). Albert H. Dell, John H. Kuck, and Jules H. Sreb, Washington, D. C., assignors to the U. S. Navy.

Electrically operated projectile fuze with a switch connected to explosive means. When the fuze melts by heat upon ignition of a thermal means, centrifugal force moves a weight connected to an arm actuating the switch to set off an explosion, destroying the projectile.

Jet driven sustaining rotor (2,776,016). Harris S. Campbell, Byrn Athyn, Pa., assignor to Autogiro Co. of America.

Jet carried at the end of the extension of a helicopter rotor. A pivot provides angling movement of the aeroform contoured extension relative to the blade axis. The jet, located well beyond the blade tip, gives the applied power a moment arm greater than would obtain if the jet was located at the blade tip.



Jet propulsion engine with afterburner (2,775,864). Harry C. Karcher, Indianapolis, Ind., assignor to General Motors Corp.

Turbine engine exhaust pipe terminating in a nozzle of fixed area, expanding abruptly in cross section downstream to an afterburner area. Exhaust pipe walls are double. Inner wall receives and circulates gases discharged adjacent to the turbine passage boundaries to cool the walls.

EDITORS NOTE: Patents listed above were selected from the Official Gazette of the U. S. Patent Office. Printed copies of patents may be obtained from the Commissioner of Patents, Washington 25, D. C., at a cost of 25 cents each; design patents, 10 cents.

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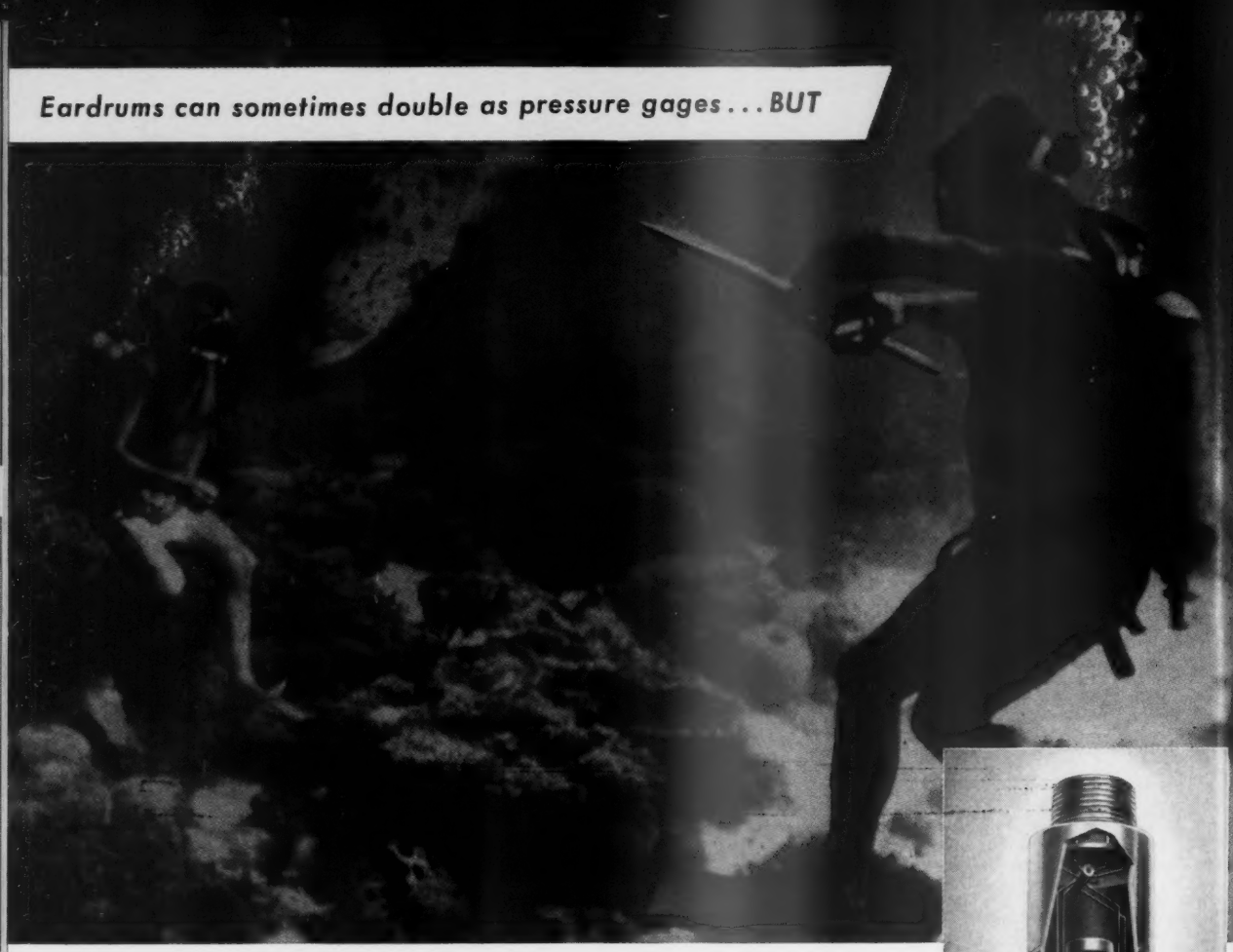

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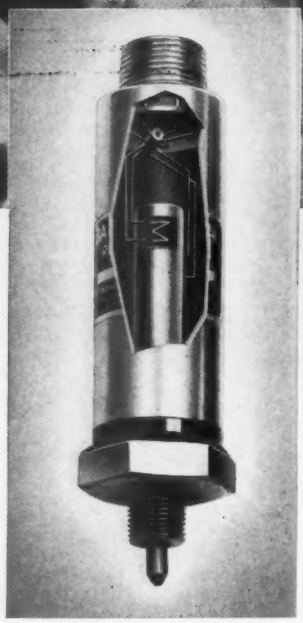

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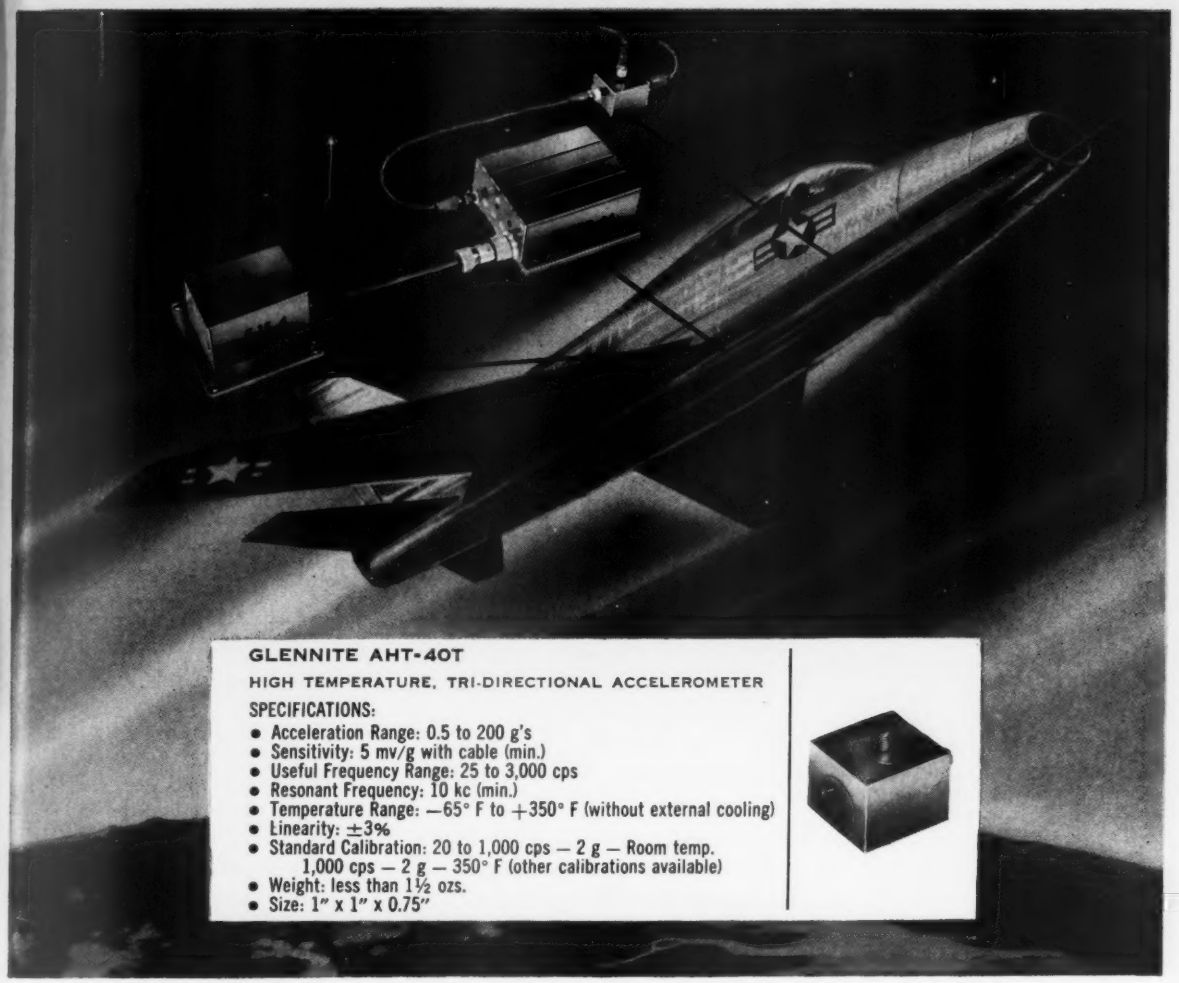

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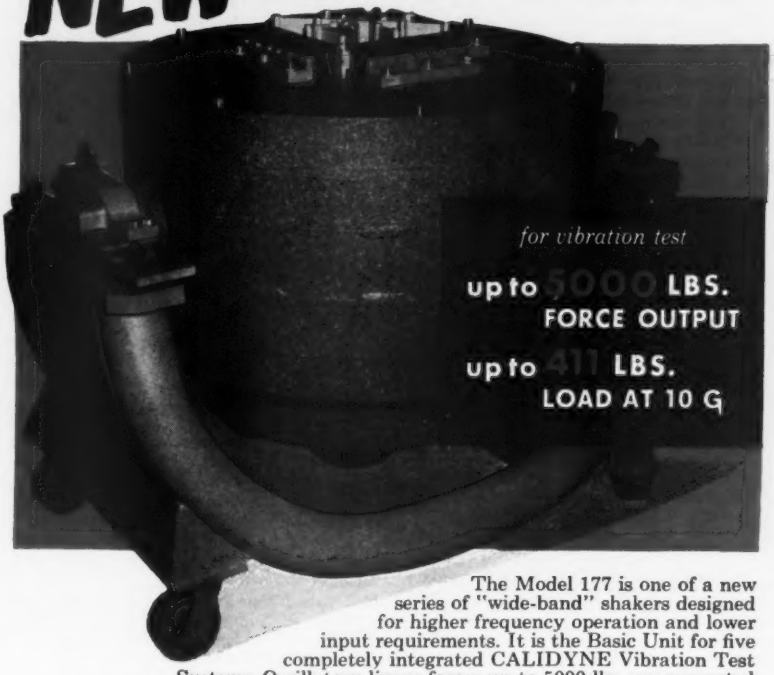

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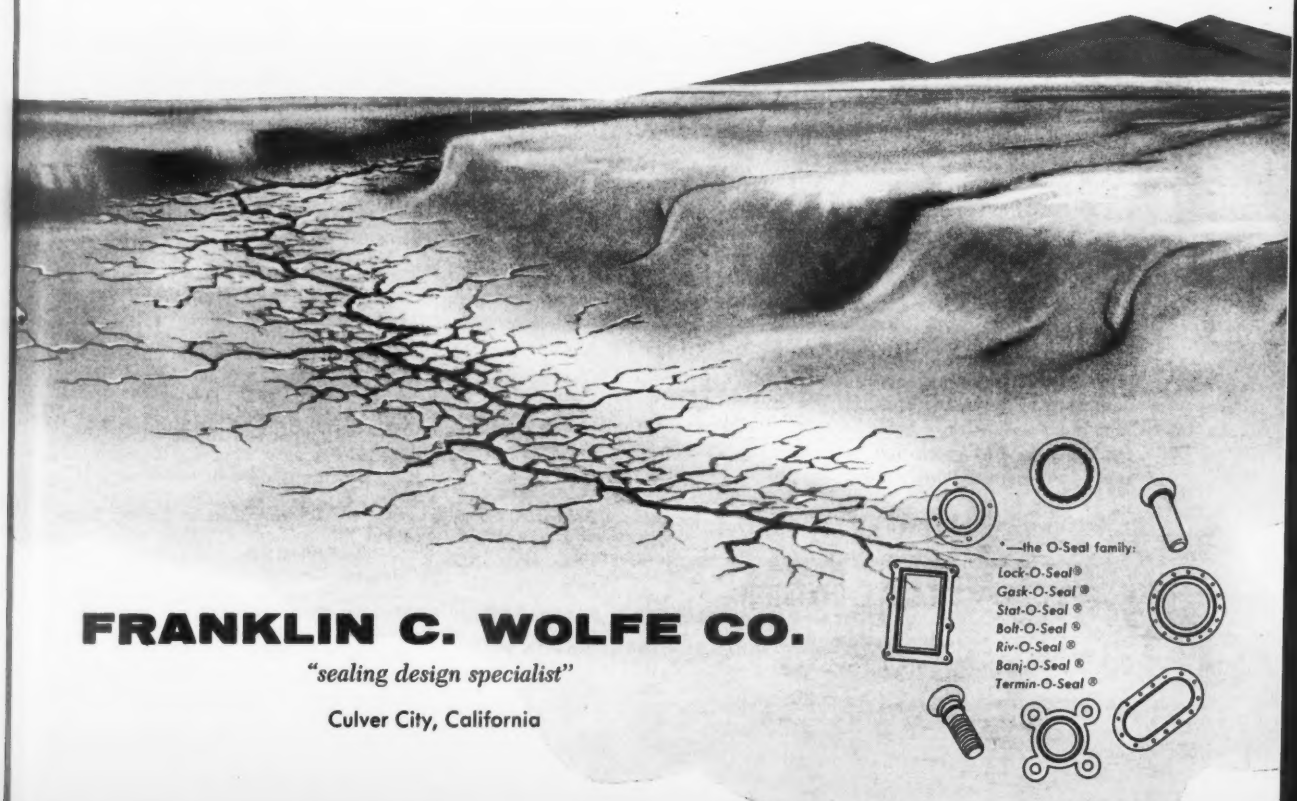

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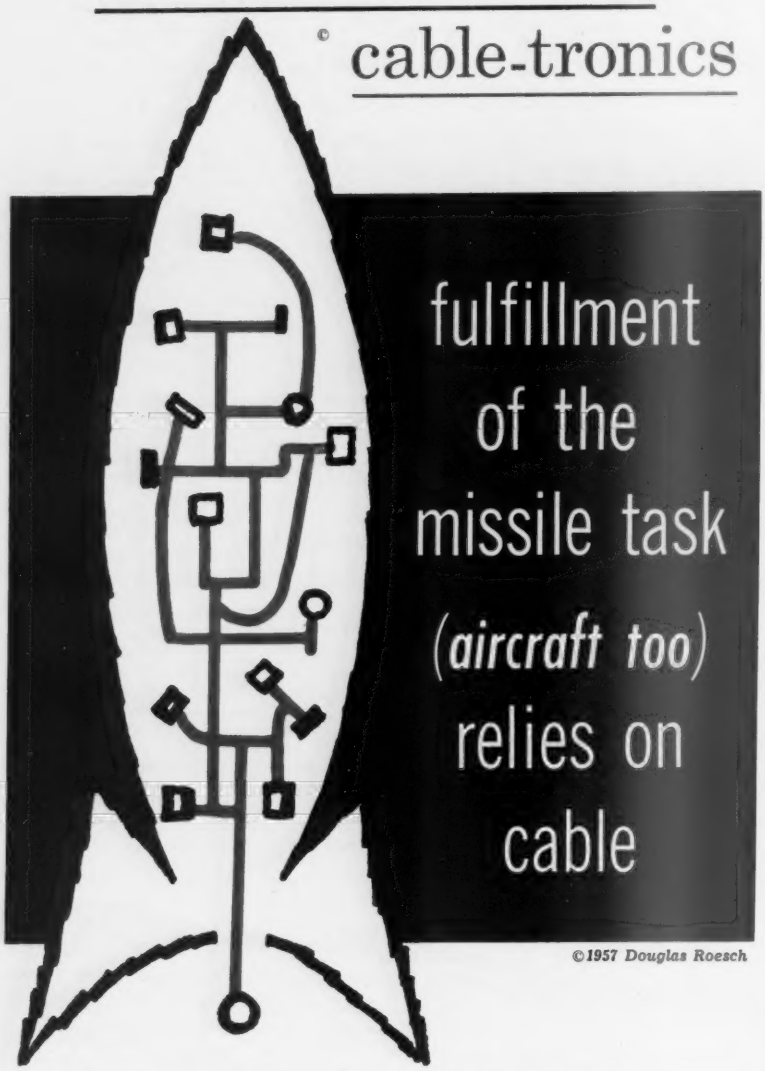

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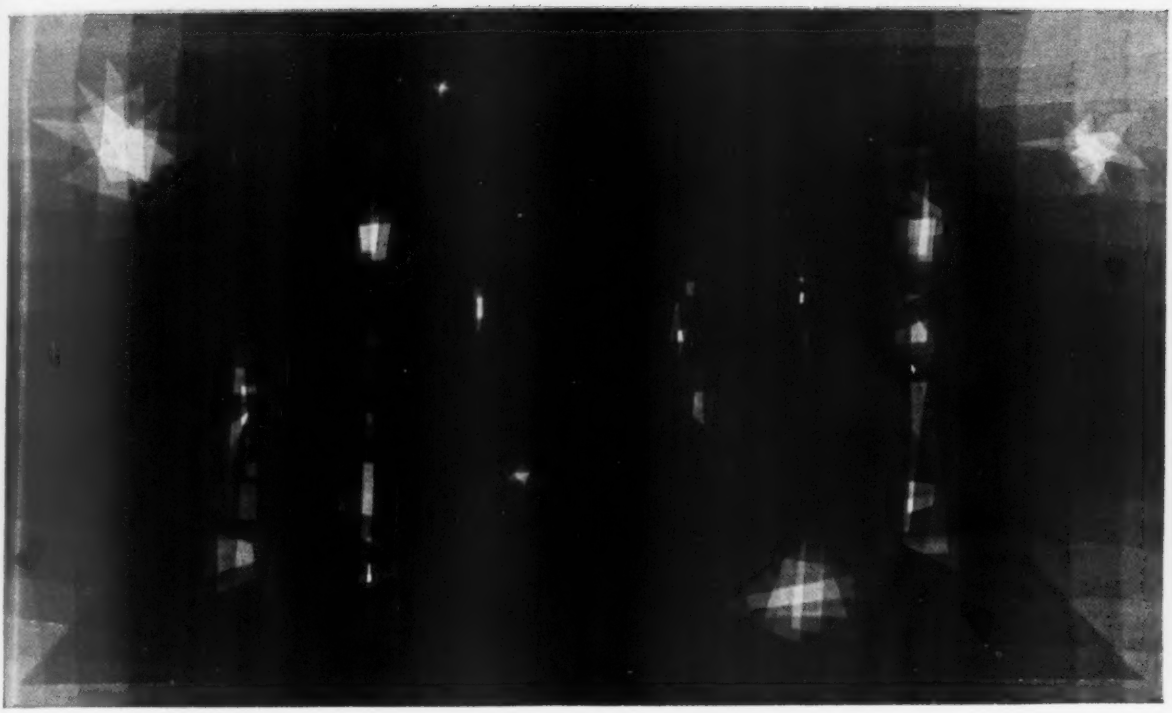

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